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Geobiology

LOURENS G.M. BAAS BECKING

ALEXANDER J.P. RAAT (Ed.)

Geochemical Perspectives

Each issue of ***Geochemical Perspectives*** presents a single article with an in-depth view on the past, present and future of a field of geochemistry, seen through the eyes of highly respected members of our community. The articles combine research and history of the field's development and the scientist's opinions about future directions. We welcome personal glimpses into the author's scientific life, how ideas were generated and pitfalls along the way. *Perspectives* articles are intended to appeal to the entire geochemical community, not only to experts. They are not reviews or monographs; they go beyond the current state of the art, providing opinions about future directions and impact in the field.

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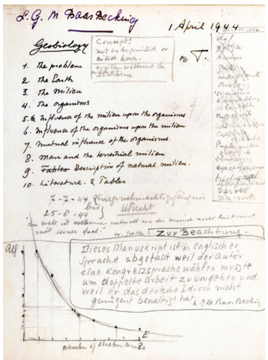

About the cover

Front page of Baas Becking's manuscript *Geobiology*, dated 1 April 1944, including the table of contents, a graph of the function of Respiratory Quotient and the number of electrons removed from the C atom, several notes addressed to German guards and a list of subjects meant as a reminder. See more details on page 2.

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FOREWORD

Lourens Baas Becking is a pivotal figure in the history of microbial ecology and geobiology, having coined the term "Geobiologie" in the title of his 1934 opus (*Geobiologie of inleiding tot de milieukunde*). This work has been translated into English (Baas Becking, 2016), so everyone now can read of Baas Becking's contributions and see for themselves the context of his most famous proposition "Everything is everywhere, but the milieu (environment) selects". One can read of many other things as well and be particularly struck by Baas Becking's fondness for extreme environments and, generally, how much was known about the microbial ecology of aquatic ecosystems in the 1930s.

This was not, however, the end of Baas Becking's writings about geobiology. Without revealing too much in this foreword, Baas Becking was imprisoned for trying to escape Nazi-occupied Netherlands, and he wrote an updated version, in English, of the original *Geobiologie* over a seven week period during his initial stay in prison. The writing was by hand and all figures were hand drawn. This 1944 edition of *Geobiology* is the volume that is presented here.

At this point, we must introduce Lex Raat, an academic grandson of Baas Becking (his academic teacher was Baas Becking's student Anton Quispel), and the contributing editor for this volume. Lex is also the founding president of the Baas Becking Society and a keen Baas Becking scholar. Lex became aware of the existence of this manuscript and was able to purchase it with help from the Agouron Institute and the Leiden University Fund. After this, Lex spent countless hours poring over the manuscript and transcribing it into a legible form, while producing a staggering number of important footnotes. He has also extensively researched Baas Becking's life and contributed with this volume the most comprehensive Baas Becking biography in existence.

We felt that this volume would be an unusual, but also excellent, fit into the *Geochemical Perspectives* series. This volume has great historical significance, giving an excellent insight into the nature of geobiology and microbial ecology in the 1940s, as well as into the workings of a brilliant academic mind. Fitting this volume into the *Geochemical Perspectives* format has been a huge undertaking. The volume is rather long, and Rob Raiswell has done an outstanding job of proofreading. This has been a nontrivial task as Rob needed to constantly balance between expression, readability and historical accuracy. Overall, the writing has been edited with a light touch. We have also elected to use the original Baas Becking hand-drawn figures. Most of these are quite straightforward to read, but some have required additional clarification in the figure caption or as text additions onto the figure itself. A very few have needed to be redrawn.

Marie-Aude Hulshoff, managing editor of *Geochemical Perspectives*, has also done an outstanding job of coordinating everything including figuring out how to take this important, but unusual, document and putting it into something that resembles a *Geochemical Perspectives* volume.

As noted, the volume is long, and in a break from normal *Geochemical Perspectives* tradition, will only be offered online. However, this also offers some advantages as one can easily access footnotes from the text.

Overall, the editors of *Geochemical Perspectives* hope that you enjoy this volume.

Donald E. Canfield
Biology Institute, University of Southern Denmark

PREFACE

I wrote a book about the earth and man. He was always there as a hunting dog on the trail, restless, enthusiastic, with impromptu promptings, which helped me. For example, I wrote about a city with its energy production as an organism. He gave me to read Ezekiel 27, which describes the riches of Tyrus, and when I spoke of the devastation that man wreaks on earth, he showed me places from Isaiah, and we thought of the anciently devastated land of Palestine and read the words of the prophet from my English bible: "The Earth is defiled by the inhabitants thereof."

Lourens Baas Becking about his imprisonment in Utrecht
with Professor **Victor Henri Rutgers** in July and August 1944.[1]

In 2016 an English translation of Lourens G.M. Baas Becking's *Geobiologie of Inleiding tot de Milieukunde* (Baas Becking, 1934) was published as *Baas Becking's Geobiology*, edited by Don E. Canfield, Professor of Ecology, University of Southern Denmark, Odense. The 1934 version of *Geobiologie* was the result of a series of lectures by the Leiden Professor of General Botany, Lourens G.M. Baas Becking (1895-1963) for an audience of mainly laymen. *Geobiologie* laid the foundation for geobiology and environmental science as academic disciplines. Until this day Baas Becking is mostly remembered outside his native country by his summary in *Geobiologie* of Beijerinck's 'law' about the global distribution of microbes: *Everything is Everywhere* but *the Milieu Selects*.

In the early 1970s I had been a student of Anton Quispel (1917-2008), from 1960 to 1983 Professor of Experimental Botany in Leiden. He was successor of his former supervisor Baas Becking, who occupied the academic chair from 1931-1945. Quispel had a great admiration for his teacher, which he made clear to his students. Every Leiden biologist of my generation is therefore familiar with Baas Becking's ubiquity law.

In May 2017 Peter Westbroek, Professor Emeritus of Geophysiology in Leiden, drew my attention to the translation of Baas Becking's *Geobiologie*. He also convinced me to organise a meeting to receive Don Canfield during his visit on December 1, 2017, to the Leiden Hortus Botanicus and the former Botanic Laboratory of Baas Becking. I prepared a short presentation and founded the Baas Becking Society to which I invited botanists, microbiologists and geochemists who were involved with the Laboratory in the 1970s.

The result of my early quest was the rediscovery of an English manuscript *Geobiology*, a copy of a typescript of 830 pages by Baas Becking that was largely finished in Australia. It was an updated and thorough revision of his *Geobiologie* (1934), this time for an academic audience. However, the manuscript (Baas Becking, 1953a), supplemented with Baas Becking's handwritten additions until 1953, remained unpublished, because his publisher suggested changes that were unacceptable for Baas Becking.[2]

The original typescript (*circa* 220,000 words) with annotations in ink, came in 1979 into possession of the Royal Netherlands Academy of Arts and Sciences (KNAW) in Amsterdam, as a gift of Baas Becking's former secretary Mrs. Elisabeth Johanna Drágffy van Peski (1902-1980), who typed the original version. In 1983 it was judged by the Section Biology of the Academy as of historical value but outdated and therefore no longer suitable for publication. Unfortunately, the original typescript is now untraceable and probably no longer in the KNAW collection.

I knew that a still earlier version of *Geobiology* existed.[3] This was written by Baas Becking in July and August 1944 in the Utrecht *Kriegswehrmachtgefängnis* [German army prison in wartime]. After being convicted by a German naval court for a failed attempt to escape to England, he spent seven

1 Professor Rutgers did not survive his imprisonment, he died on February 5, 1945, in the German prison of Bochum. See De Gaay Fortman (1946), the quote from Baas Becking is on p. 51-52.

2 In the Baas Becking archive of the Australian Academy of Science there is a map with the complete correspondence between Baas Becking and Frans Verdoorn about the publication of *Geobiology*. Australian Academy of Sciences (AAS) Adolph Basser Library Manuscript Collection 043 nr. 161. Letters Chronica Botanica Company. In 1954 he tried to publish the manuscript with the Chicago University Press. In 1961 he was in touch with Elsevier in Amsterdam about publishing his waterbook. AAS Basser collection 043 nr117 and nr.152.

3 From H.F. Linskens, Professor of botany Radboud University Nijmegen, in the Dutch *Vakblad voor Biologen* in 1983. See Linskens (1983).

weeks with his fellow refugee, the politician and former minister Professor Victor Henri Rutgers (1877-1945), in the Utrecht prison awaiting transport to the German *Zuchthaus* Siegburg. In the late 1970s it had been in possession of Mrs. C.J. ('Tine') Niekerk-Blom (1902-1986), a biologist and intimate friend of the family, who probably donated the manuscript to H.F. Linskens, Professor of Botany, Radboud University, Nijmegen. In November 2017 I found this version of *Geobiology* in the catalogue of the autograph dealer Thomas Kotte in Rosshaupten, Germany. Unfortunately, it took 14 months before I could obtain the document. Like the 1953 *Geobiology* typescript in Amsterdam, the 1944 manuscript in Rosshaupten turned out to be untraceable. In January 2019 however, it was finally found in the Rosshaupten autograph collection and sent to me. Then I decided on a thorough investigation of Lourens Baas Becking's *Geobiology*. The result of that decision is the present annotated edition of *Geobiology*, whose transcription and annotation have provided me with comfort during the past two years of corona lockdowns and concerns about the health of my dear wife.

Geobiology (1944), a 388 page ledger written in pencil in small difficult, barely legible handwriting, is not only a unique biological treatise, but also a 'document humain'. Baas Becking's personal circumstances are clearly reflected in the manuscript. *Geobiology* gives an impression of his ideas as a botanist, physiologist and microbiologist of the symbiosis of life and earth. The manuscript also shows his multifaceted interest in fields other than those of his expertise. Baas Becking was well acquainted with the contemporary knowledge and research of geology, astronomy and biochemistry. In addition, he was able to apply mathematical, statistical and physical techniques to biological problems. *Geobiology* was written in prison in a threatening situation with a real chance of the author not surviving it. Moreover, he had to work under circumstances of a very limited access to the resources necessary for such an undertaking. Seen from that perspective *Geobiology* is his intellectual last will, a scientific testament.

Compared to the later, more elaborate and extended 1953 version, which was mainly based on literature of post-war research, the 1944 version of *Geobiology* is much more impulsive, because the nearly 65,000 words were feverishly written in only seven weeks. The text is largely based on his own pre-war research and that of his colleagues and PhD students and it further demonstrates his understanding of the development of physiology and microbiology in Germany, France and the United States over the previous 100 years.

Although *Geobiology* (1944) is unfinished and has major gaps, it remains an inspiring memoir of a scientist who records his enlightened vision on the relationship between life and earth. Long before James Lovelock and Lynn Margulis defined the Gaia hypothesis in the early 1970s as, "the notion of the biosphere as an adaptive control system that can maintain the Earth in homeostasis," Baas Becking attempted to "describe the relationship between organisms and the Earth." [4] Already in 1931 that had been the subject of Baas Becking's inaugural address, *Gaia or Life and Earth*, in Leiden. However, contrary to that academic oration, the manuscript written in the Utrecht prison is not only the visionary perspective of a well informed and creative scientist, but also a personal complaint of a geobiologist over the disastrous treatment of the earth by man. In the manuscript of *Geobiology* he introduced a broad concept of symbiosis, and extended it to man's place in the biosphere: *Man is not alone*, and, as all other organisms, is highly dependent on the other participants of the biosphere. Man is part of a general symbiosis in which he must participate, but where he has made himself responsible for the stimulation of different aspects of dissipation.[5] *Geobiology* (1944) provides a gripping and unique image of the man and his time, as well as an insight into Baas Becking's biological experience and feelings of despair. Therefore, this version of *Geobiology* still has sufficient topical value, even after 75 years, to be published as a *Geochemical Perspectives*.

Utrecht, February 10, 2022

Dr. Alexander J.P. Raat

*Baas Becking Society in the Leiden Hortus Botanicus, December 1, 2017. In the background the former Botanical Laboratory and office of Lourens Baas Becking. **From left to right**: Prof. Pieter Baas, Prof. Peter Westbroek, Dr. Hans van Gorkom, Prof. Rob Hengeveld, Prof. Kees Libbenga, Hein Raat MSc, Dr. Alexander J.P. Raat, Prof. Don E. Canfield, Prof. Jan Wijbrans, Carolus Clusius (1526-1609), Prof. Jacques van Alphen, Marijke Libbenga MSc, Dr. Judith de Jong, Prof. Marcel Donze, Dr. Kees Planqué.*

4 Quotes from Jan Sapp (1994, p. 194) and from Baas Becking (1934, p. 5; 2016, p. 3).

5 Quote from Quispel (1998, p. 71).

LOURENS GERHARD MARINUS BAAS BECKING (1895-1963)

Baas Becking was undoubtedly one of the most gifted biologists of his time and he also had great talents in other fields of science and in that of art. His ideas were almost always original and often with a touch of a genius. However, his mind was so restless that he usually did not allow himself the time to test and elaborate these ideas thoroughly, because new thoughts captured him. That same restlessness and mobility characterised his entire personality; he was brilliant, witty and idealistic, but also emotional and out of control and therefore not always fair in his judgment, often with an urge for the romantic and heroic.

Victor J. Koningsberger (1963)

Introduction

The motto written by Lourens Baas Becking's friend and former fellow student Professor Victor Koningsberger, gives an impression about his talents and character. It is a sketch of a dominating man and a brilliant and inspiring biologist. If we survey his life and work however, the picture is less exuberant. The ambitious student, researcher, Professor in Stanford and Leiden, Director of the institutes of the Botanic Garden in the Dutch East Indies is another person than the scientist after the war. Baas Becking was traumatised through the fearful experiences of terror in Europe, the Indonesian National Revolution and by the conflicts in his professional and the calamities in his personal life. The ambition had been replaced by bitterness, disappointment and grief. His efforts after the war in the coordination of scientific research in Indonesia, the directorate of the Bogor Botanic Garden and his work for the Research Council of the South Pacific Commission were unsuccessful, mainly because of his inflexibility. Nevertheless, he was able to spend the last ten years of his life in Australia working as a respected researcher without the burden of great responsibilities. He remained fascinated by life as a process, however he continued to be cynical and ruthless when he described the role of humans in that process and in the destruction of life on earth. All in all, his life and works evoke both admiration and compassion.[6]

Youth and Study in Delft and Utrecht (1895-1919)

Lourens Gerhard Marinus ('Lou') Baas Becking was born January 4, 1895 in the Dutch provincial town of Deventer. He was the youngest son of Marinus Ludovicus Baas Becking (1844-1904) and his 21 year younger wife Anna Maria Helena Berkhout (1865-1941). Lou's father had been an administrator of Oud Djember, a tobacco estate in Besuki (East Java) in the Dutch East Indies. In April 1888, a year before his marriage in June 1889, Marinus Ludovicus returned to Deventer and became an agent for George Birnie, the owner of the Oud Djember tobacco company. Lou spent his early youth in Deventer and The Hague with his parents, sister Anna Gerharda Hermanna (1892-1969) and his brother Jan Floris (1893-1906).

His mother was the central person of his youth, his father died in 1904. In 1908, two years after his brother's death the family moved to Amersfoort. There his mother kept a boarding house for children whose parents were in the Dutch East Indies. In The Hague his mother had been active in the *Rein Leven Beweging* [Pure Life Movement]. This movement, founded in 1901, was based on Leo Tolstoy's Christian anarchist and pacifist thought. In Amersfoort, Lou's mother was actively involved in all kinds of initiatives in the field of women's emancipation. Lou was since 1908 a pupil at the *Rijks HBS*, a secondary school in Amersfoort. His natural history teacher was Dr. Theodorus Weevers, a student of Hugo de Vries and since 1924 Professor of Plant Physiology and Pharmacognosy in Amsterdam. He must have stimulated Lou to botanise in the area around Amersfoort.[7] In his inaugural address in Leiden *Gaia of Leven en Aarde* [*Gaia or Life and Earth*] (Baas Becking, 1931b), Baas Becking thanked him, "because he developed and led his interest in botany." In July 1913 Lou graduated from secondary school and went to the Technical Highschool (the present Technical University) in Delft, to become a chemical engineer.

In Delft he followed courses in mathematics, theoretical and applied physics, chemistry, mechanical technology and mineralogy. He was an editor of the *Studenten Weekblad* [*Students Weekly*], in which he published a romantic, naturalistic poem. Although he had serious asthmatic complaints, he was an active student. According to Jacoba Ruinen his great energy expansion gave rise in Utrecht to the saying that Baas Becking could assist for 8 hours, study for 8 hours and make time to party for the rest of the 24 hours. In May 1914 he left Delft

6 The summarised 'Life and Works' of Baas Becking is based on published and unpublished documents. The unpublished documents are kept today in the Adolph Basser Library Manuscript Collection (reference MS 043) of the Australian Academy of Science (AAS) in Canberra, The Leiden University Library, the Leiden Academy Historical Museum, the library of the Leiden Museum Boerhaave (Letters Baas Becking to F.A.F.C. Went), the National Archive (NA), The Hague, the Baas Becking family in Australia and my personal archive. Further information was taken from the biographical sketches of Jacoba Ruinen (1963), Victor J. Koningsberger (1963), Frits Went (1963), Quispel (1998) and Marius Jacob's biography of Hermann Lam (1984). For the American period, *The Daily Palo Alto* was a useful source.

7 'Verslag van een excursie die van 17 tot 21 juli 1910 is gehouden in de omstreken van Tilburg en de daaraan verbonden vergadering'. In: *Nederlandsch Kruidkundig Archief* (1911). Serie 3, v. 21, p. 44-47.

without the propedeuse degree. Nevertheless, the year and a half in Delft had been a particularly formative period for Baas Becking. It is probable that his admiration for the work of the Delft Professor Martinus Beijerinck was aroused at that time.

Baas Becking left Delft because it was no longer necessary to be graduated from a Gymnasium to enter University. So, Lou enrolled as a student of botany and zoology in the Utrecht University. He returned to his mother's house in Amersfoort and became a 'railway student'. From the later correspondence with his supervisor the Utrecht Professor of Botany and Director of the Botanical Garden F.A.F.C. Went (1863-1935), it is clear that he must have built up personal contacts with other Professors in Utrecht: the plant taxonomist A.A. Pulle, the zoologist H.F. Nierstrasz and the physiologist H.J. Jordan. After graduating, he kept in touch with many of his former fellow students, such as Victor J. Koningsberger, Herman J. Lam, Henri G. Derx and Huib van Mook.

In 1917 he became a member of the *Netherlands Botanical Society*. He published two papers in *De Levende Natuur*: on the relationship between the different forms of common club moss (1917) and another on deviating shapes of the flowers of orchids (1919).[8] In April 1918 he was appointed with Victor Koningsberger, assistant in the botanical laboratory of his mentor F.A.F.C. Went. For his graduation he chose a genetic topic. His premise was that "for certain applications of the Mendelian laws, an all-encompassing treatment of mathematical heredity is still lacking." He published three papers on numerical relationships in panmictic populations that testify to his knowledge of mathematics and probability theory.[9] He concluded that testing his theoretically obtained results "would be of some interest in practice on one and the same population." But he wondered "whether a mathematical treatment of more complicated problems (factor coupling, crossing over, *etc*.) would give results that correspond to practice." In June 1919 he graduated cum laude as a biologist.

Two days after his graduation Baas Becking married Rabina Haverman (1892-1949). Rabina ('Bine') was the daughter of the Hendrik Johannes Haverman, a portrait painter in The Hague, and Carolina Birnie, also a painter. Carolina was the daughter of George Birnie, the owner of the Oud Djember tobacco company. After finishing school Rabina spent two years in London (1908-1910), "to learn the finesse of haute couture sewing", as her daughter Daya wrote in her memoires. In 1911 she went for several years to rural Bradner (Abbotsford) in Canada. There her brother Philippe and her uncle Gerard Louis Johan ('Louis') Birnie had bought pieces of land in the wilderness near the Fraser River to exploit their property as agricultural land. Louis Birnie was married to Louise ('Wies') Berkhout, the sister of Lou Baas Becking's mother.[10]

The married couple left shortly after his doctoral examination for California, according to Jacoba Ruinen "on medical advice, which also applied to his young wife Rabina Haverman." He did not seek his career in the Dutch East Indies, like many of his contemporaries.

Doctor's Degree of Stanford and Utrecht University (1919-1921)

Early October 1919, Lou and his wife Rabina arrived at Stanford University in Palo Alto. They had travelled by boat to Philadelphia. On board they met Adriaan van Maanen, a Dutch astronomer who had worked since 1912 at the Mount Wilson observatory in Pasadena. They stayed several days at Pasadena, where they met the American astronomer Harlow Shapley. The discussions with Shapley and Van Maanen may have given Baas Becking the idea of relating changes in the emission and absorption spectrum to physiological processes in living organisms. This became the basis of his doctor's thesis *Radiation and Vital Phenomena*, in 1921 in Utrecht.

In December 1919 however, he started his Stanford PhD research on the embryology of the eusporangiate ferns *Botrychu*
11 Douglas Houghton Campbell (1859-1953) American botanist.
Campbe
University.[11] To his mentor in Utrecht Professor Went he confessed, "I consider the work I do under Dr Campbell to be a necessary part of my botanical education! In the future it will not be my line." In March 1921, he wrote to Went: "I must tell you frankly that I am glad that the work under Campbell has ended. The material was so rare that I shivered when I had to cut it. Fortunately, none of the 6 prothallia failed – so that I can keep 21 slides (of which I can keep 10 for the lab. in Utrecht)." Apparently, the experimental work for his PhD dissertation was finished within fifteen months. February 24, 1921 the final oral examination for his degree of Doctor of Philosophy was held in Palo Alto. Shortly afterwards Lou and his wife Rabina returned to Holland for a period of eight months. So, he was not present on June 20, 1921, when President Ray Lyman Wilbur awarded Baas Becking the doctor's degree.

In February 1920, he received a university fellowship paying $750 *per* year, "at least a useful addition", in view of "my wife's health." In August 1920, he was appointed acting instructor in botany, "lecturer" according to Baas Becking, for the autumn and winter quarters of 1920-21. *The Daily Palo Alto* explained: "He will conduct work in plant physiology before leaving for Holland to engage in botanical work there." Baas Becking replaced the plant physiologist Professor George James Peirce, who took a sabbatical to update his *Plantphysiology*, which, incidentally, was characterised by Baas Becking as "below all criticism (this sub rosa)."

Lou and Rabina lived on what he earned as a tutor. Together they made microscopic series preparations in the evening for additional money for the Drosophila research of T.H. Morgan. On May 28, 1921, on leave in Holland, he gave a scientific address in Utrecht for the *Netherlands Botanical Society*, which made, according to Koningsberger, "a deep impression." During his lecture Baas Becking demonstrated the microscopic preparations of the cytological studies of C.B. Bridges in Morgan's laboratory: "In Holland there were doubts about the correctness of Morgan's theory that the genes in the chromosomes are arranged linearly and that in factor coupling one has to deal with genes that are located in the same chromosome. Unequivocally, the opposite was apparent from the preparations of Baas Becking, which led the doubters to change their minds."[12]

8 Baas Becking (1917, 1919a).
9 Baas Becking (1918, 1919b, 1919c).
10 See for the Birnie family: Elisabeth Birnie (1992). *De Birnies*. Twello. See for Rabina Haverman's youth Daya Teding van Berkhout (2010).
11 Douglas Houghton Campbell (1859-1953) American botanist.
12 *Algemeen Handelsblad* 4 juni 1921, p. 3.

October 21, 1921, Baas Becking obtained in Utrecht his second Doctorate cum laude for his remarkable very hastily written thesis *Radiation and Vital Phenomena*.[13] His idea was to draw up a law of conservation of energy for a biological process, in which all forms of energy were taken into account, including the then relatively unknown radiation energy.[14] Baas Becking based the concept of his thesis on the experiments on Brownian motion of the French physicist and Nobel Prize winner Jean Perrin, which he summarised as: "In every system there is an equilibrium between "normal" and "active" molecules, only the latter taking part in the chemical reaction. Rise in temperature will cause more of these activated molecules to be formed. In the period 1909-1919 the basis for this activation was sought in the influence of radiation." He acknowledged the advice of Harlow Shapley, at that time director of the observatory of Harvard University and David L. Webster, Professor of Physics at Stanford, who published on the theory of quantum emission, radiation, absorption and heat emission. He also referred to the Utrecht Professor of Theoretical Physics Leonard Salomon Ornstein and the Dutch Nobel Prize winner physicist Hendrik Lorenz.

In *Geobiology* (1953) he reviewed his effort to account for the temperature sensitivity of vital reactions by means of Perrin's hypothesis: "Later work has shown Perrin's theory to be unsatisfactory, radiation alone being clearly insufficient to account for chemical activation."

Career in Stanford University (1922-1927)

In January 1922 Baas Becking returned to Stanford, as an instructor in the Botany Department, for the courses usually given by Professor Campbell. On his way to Palo Alto, he looked up Wintrop Osterhout and Jacques Loeb, editors of the *Journal of General Physiology*, in the Marine Biological Laboratory in Woods Hole: "They are interesting people, anyway. Loeb had nominated me for a national research fellowship. With this venerating paper, I went to the president of our university, who has now taken steps that will allow me to stay here." September 1, 1922, he was appointed as a staff member at Stanford University as an assistant Professor in Economic Botany. His salary raised from $1800 to $2500. In March 1925 he became an Associate Professor of Economic Biology.

For his colleagues in The Netherlands, he made translations, such as 246 botanical descriptions for the Utrecht Professor Pulle and a chapter in a book of the physiologist Professor Hendrik Zwaardemaker.[15] It took him too much time. Meanwhile he also did chemical advisory work as a consultant in plant physiology for the Bureau of Chemistry in Washington, with special assignment to diagnose frost damage in orange groves. The content of his publications shows an expansion of his interests. As a follow up of his Utrecht dissertation, he published research on the effect of light on the permeability of lecithin (1924). In 1925, together with Leland Baker, he wrote a mathematical treatise on growth, a subject that he would continue in later years with his Leiden PhD student E. Drion (1936) and in 1946 with an *Analysis of Sigmoid Curves*. In a letter to Went (May 1924) he summarised his conclusion: "No simple laws can be derived for growth rate, cell length, number of cells and length of cell chains." As well, a start was made with microbiological work, which later took a permanent place in his study of extreme environments and of symbiosis. From 1924 on he published on sulphur and purple bacteria, iron organisms, coralline algae, *Dunaliella* and the metabolism of autotrophic bacteria. In the 1930s this research was continued by his students in Leiden.

In July 1923 his son Jan Matthias was born in Palo Alto. Two years afterwards, in June 1925, a second son Hendrik Gerhard ('Dick') was born. In his correspondence with Professor Went in Utrecht Baas Becking referred to camping weekends of the family along the Pacific coast.

In February 1924 Baas Becking organised an exhibit in the library of Stanford, which resulted from his paper on Van Leeuwenhoeck in *Scientific Monthly* (Baas Becking, 1924a). A report in *The Daily Palo Alto* gave an impression of Baas Becking's knowledge of the history of microbiology, which is also evident in his 1944 and 1953 manuscripts of *Geobiology*. In 1931 he published another historical study, *Historical Notes on Salt and Salt Manufacture*, also in *Scientific Monthly* (Baas Becking, 1931c). In the unpublished 1953 version of *Geobiology* this topic was updated and supplemented with data he had collected in California, Portugal, Indonesia and Australia in the 1920s and 1930s.

Miquel Professorship in Utrecht (1927-1928)

From the correspondence with his former PhD supervisor F.A.F.C Went it is evident that Baas Becking had strong ambitions. His critical and often arrogant comments on his colleagues can be found in the letters as early as 1919. Already in 1924, Went promoted him and Victor Koningsberger as Director of the Amsterdam Hortus, a position that Hugo de Vries' pupil T.H. Stomps eventually obtained. Baas Becking wrote in December 1924 from Stanford: "Too bad Victor [Koningsberger] or I didn't get Amsterdam! Whether we can compete with Stomps!! That doesn't seem very difficult to me. If I ever came to Holland, Professor, I would seriously try to be a second Westerdijk!" He referred to the plant pathologist Johanna Westerdijk, in 1917 appointed in Utrecht as the first female Professor in The Netherlands. In 1924 her portrait and those of Beijerinck and Went were on his desk.

From 1925 on Baas Becking tried to arrange a temporary exchange with a Dutch Professor. The letters to Went show his insistent and restless approach: "Professor Pulle is unable to exchange with me in 1927. I tried Nierstrasz, but have little confidence he will care to come. The people have been sitting so long in their easy chairs that I am sure they have a rather exalted idea about Dutch science, and think in their innermost

13 Eric A. Bergshoeff, remarked about the thesis: "The point is that Baas Becking was one of the few and perhaps one of the first as a biologist to be open to new developments in physics. It is clear that he also communicated with colleagues outside his own field. That shows an open mind." Jacoba Ruinen (1963) characterised the thesis: "a quantum theoretical reflection on photosynthesis, which was well before its time." Victor Koningsberger (1963) remarked: "Baas Becking's thesis *Radiation and Vital Phenomena*, for which he obtained his PhD laude, he had largely edited in the United States. It is a curious, mainly mathematical treatise, inspired by the statement of J. Perrin: "toute réaction chimique est provoquée par une radiation lumineuse". A quantentheoretical treatment of biological data available for this purpose, still insufficiently exact, led, among other things, to interesting considerations about the biologically important temperature coefficient."

14 I am grateful to my friend Eric A. Bergshoeff, Professor Emeritus Theoretical High Energy Physics (University Groningen), who carefully supplied me with his comments on Baas Becking's thesis (email May 24, 2020).

15 Reference to the Utrecht Professor in Physiology Hendrik Zwaardemaker (1857-1930) and his research in bioradioactivity. According to Zwaaardemaker the low radioactivity of potassium in the human body was responsible for the activity of the heart. He supervised at least 25 PhD theses to support his ideas, which are at present no longer considered as valid. See Simon (2006).

conscience that a position in this country is vastly inferior to a Professorship in one of the Dutch fresh-ware universities (October 6, 1925)."

No exchange took place however, but in June 1926 Professors Went and Pulle arranged a grant of 4000 florins from the Miquel Fund for his sabbatical year (April 1927-June 1928) in Utrecht. Baas Becking wrote to Went: "Your hospitable offer has touched us very much and we feel now that with the additional amount from the Holland-American Foundation and my one-half pay and some consultation funds, I hope to collect this summer, we will be able to make the trip without borrowing more money from my already indignant relatives (June 23, 1926)."

During his absence in Europe his former fellow student in the Utrecht Botanical laboratory, H.L. van de Sande Bakhuyzen, would replace him as acting assistant Professor of Economic Biology. Van de Sande Bakhuyzen ('Bakkie'), arrived in February 1924, as a research associate at the Stanford Food Research Institute. He worked on a monographic study on the growth of *Triticum*, under the auspices of Hoover food research.[16] His wife Henriette Francisca Gerhards, who obtained her doctor's degree in Stanford in May 1927, was co-author of Baas Becking's *The Physical State of Protoplasm* (1928). She followed very carefully the Brownian movement of fine granules in the outer layers of protoplasma of *Spirogyra*. L.V. Heilbrunn, a well known expert on protoplasm research of the Marine Biological Laboratory in Woods Hole, "admired her patience and care that went into what must have been a very trying series of measurements", but remarked that the senior author, "was apparently not too well aware of just what his collaborators had done. There were occasional contradictions, not infrequent misquotations of the literature, and other evidences of carelessness."[17] Baas Becking, in a letter to his mentor Went called it "an impossible critique of my viscosity piece in protoplasm by friend Heilbrunn, who is generally mistaken for querulant here."

The Daily Palo Alto reported April 7, 1927 that "Dr. and Mrs. Laurence B. Becking and their two children sailed recently from San Francisco for Holland, where Dr. Becking will hold the Miquel Professorship at the University of Utrecht during the next academic year. They will visit relatives during the intervening month. Dr. Becking will return to Stanford in June 1928. The Miquel Professorship is an honor conferred ordinarily only once in four years."

On October 3, 1927, Baas Becking delivered his inaugural address *Over de Algemeenheid van het Leven* [*On the Universality of Life*] in Utrecht. Four days later he started the course *General Physiology of the Cell*. His notes for the course are kept in the Adolph Basser Library Manuscript Collection, in Canberra Australia.[18] The programme is divided into 31 topics that are grouped into four main sections: Introduction, Internal Environment, External Environment and Organization in Environment. Each week one or more topics were discussed. The course lasted until April 1928. The outline of the course is broadly the work plan for *Geobiologie*.

Herzstein Professor and Director Jacques Loeb Laboratory, Hopkins Marine Station (1928-1931)

In June 1928 the Baas Becking family travelled back to Stanford *via* Guatemala, Panama and Nicaragua. He confided to Went: "It will be difficult to start work in the Stanford environment. I was so wonderfully established in Utrecht, but if I've learned anything this year, it's the atmosphere of a laboratory where things are done – and maybe I'll be able to create that atmosphere, at least partially in the new laboratory."

In March 1926 it was already decided that Baas Becking on his return to the United States would be staying at the Hopkin's Marine Station at Pacific Grove. In 1928 Stanford University provided additional facilities at the Marine Station for the research programme in biological sciences. The research in physiology came under the general direction of Baas Becking, who also held the newly created Herzstein Professorship of Biology. According to *The Daily Palo Alto*, the new unit of the Hopkins Marine Station was called the Jacques Loeb Laboratory for Marine Physiology, in honour of Jacques Loeb, who a few years ago made his startling experiments and discoveries in artificial parthenogenesis near the place where the new laboratory was erected. To the staff of the Laboratory belonged the Japanese chemist Tadaichi Y. Hashimoto (assistant Professor), Harold Mestre (assistant Professor) and C.R. ('Kees') van Niel (associated Professor).

Baas Becking had been the supervisor of Mestre, who obtained his doctor's degree for work on chlorophyl and photosynthesis in 1928. In late 1927, during his sabbatical, Baas Becking offered Van Niel a position as microbiologist at the new Jacques Loeb Laboratory. He had just successfully finished his PhD thesis at the Delft laboratory of Beijerinck's successor Professor A.J. Kluyver. In December 1928 Van Niel arrived in Carmel with his wife and baby. One year later Baas Becking reported: "Cornelis van Niel, an extremely careful, fine worker who may still have to find himself (at least he imitates Beijerinck a bit too much). The work he has done is truly excellent." In April 1930 he wrote: "Everything he does is so world conquering that sometimes I think he's a genius and sometimes he still has a lot to learn." Van Niel remained at the Marine Station until his retirement in 1962 and became famous for his work on purple bacteria and photosynthesis.

In 1929 Baas Becking bought a house in Carmel, which indicates that he planned to remain in the United States for a longer time. In 1925 he was already naturalised as an American citizen. Before he took the decision, he had confidentially asked advice of his "guide, friend and philosopher" Went (April 1924). According to Baas Becking it was "possibly a sentimental feeling of what they call fairness", that led to his decision to naturalise: "To enjoy the many benefits offered without taking on the slightest responsibility. Working for and with people with whom you are not equal. It's half work". But he also remarked that naturalisation would make life easier in America. Although he liked his work and the opportunities of his American job, he nonetheless preferred a Dutch position above "a better career" in the States, even if that meant "sacrificing financial and health concerns – I wouldn't hesitate."

16 van de Sande Bakhuyzen, H.L. (1937).

17 L.V. Heilbrunn (1958, p. 16-17). See also Rall (2019).

18 AAS Basser collection Ms 043 nr 159, The general physiology of the cell.

Professor of General Botany Leiden University (1931)

Baas Becking's communication with the Director of the Hopkins Marine Laboratory, Professor Walter Fisher, was disturbed. Upon his return from the Netherlands in June 1928 however, he wrote: "For mysterious reasons or other reasons Fisher was most friendly and I believe that we arrived at a complete understanding". In December 1929 however, he spoke of an "armed peace" with Fisher: "It remains a paltry feeling to have been allowed to design, develop and staff a large laboratory and then see the matter "managed" by a zoological taxonomist, an ignorant about physiology and worse, who is even annoyed by it." In February 1930 he complained about "the total lack [at Stanford University] of common pursuit and the absence of a recognised academic standard makes the work of the committees I belong to a farce." This remark was made a month after he had been asked by Professor Jacob Marinus Janse, to succeed him on the chair of botany at the University of Leiden. Baas Becking replied that it would be "a heavy sacrifice to break away from everything at Stanford." Still, he showed his willingness to return to his homeland. He asked his mentor Went for an opinion, and formulated his conditions such as "a reasonable salary" and "funds to modernise the botanical laboratory". He also asked for a separate Professorship of Special Botany: "I remember just enough to call a daisy 'Bellis perenis', but someone has to teach systematics, plant geography and colonial botany. That must be a 'man from the Dutch Indies' (preferably Lam, but please don't say that any further)." He realised that Victor Koningsberger, who was at Passerun (Java) director of the experimental station of the sugar industry, was also a candidate and declared to be loyal to his friend when he obtained the position in Leiden.

Apparently, his conditions were accepted, including an additional condition of a "year leave", which he spent in 1936 to study salt lakes and salt works in Asia and Australia. October 6, 1930, he received a telegram from the curators of the Leiden University that he was appointed as Professor of General Botany. Monday November 10, 1930, *The Daily Palo Alto* announced: "Resignation of Professor Laurence B. Becking as Herzstein Professor of Botany at Stanford, to accept the directorship of the Botanical Institute at the University of Leyden, Holland, and the chair of botany at that university, was announced Friday. Becking, who is a native of Holland, has been at Stanford since 1919, connected chiefly with the Jacques Loeb Laboratory of the Hopkins Marine Station." December 30, 1930, several Dutch newspapers published a photo of Baas Becking with his dogs, "returned by S.S. Volendam in The Netherlands to take up his office as Professor in Leiden in January."

Photo published in Dutch newspapers on December 30, 1930: "Baas Becking returned by S.S. Volendam in The Netherlands to take up his office as Professor in Leiden in January. Baas Becking left with his two favourite dogs."

Leiden (1931-1939)

One week after his arrival in Leiden, Baas Becking's house was already freshly wallpapered. He paid a visit to the minister of education in The Hague. The minister "was willing to listen to his plans". In the 1930s he regularly visited the ministry on his own initiative, bypassing the curators of the university to their annoyance. When he first met his students, they asked him to organise a practical course in physiology. He immediately planned six experiments, each a full week, under the name *Meten en Rekenen* [Measuring and Calculating], a playful reference to *Door Meten tot Weten* [Through Measuring to Knowing], the slogan of the Leiden Nobel Prize winner Heike Kamerlingh Onnes.

He began his correspondence with Herman Lam at the Bogor Herbarium about the Professorship of Special Botany in Leiden. Lam set financial and practical conditions. October 1933 he finally arrived in Leiden. According to Marius Jacobs in his biography of Lam (1984), Baas Becking was at that time already an all pervading force in the faculty. He had ideas on everything. His habit of dropping ideas, making plans, inspiring others, and then moving on, terrified many. Lam kept for this purpose a diary to record his position in relation with Baas Becking. The nine volumes (1933-1948), preserved in the library of *Naturalis* in Leiden, are a rich source of information about Lam and Baas Becking's characters and activities. So, we read in Lam's notes on Thursday March 15, 1934:

> Yesterday we had a conversation with Mrs. Boshuizen, who thinks physiology is "teasing plants" and who got a telling off from Lou, because she doesn't feel much about physiology. I had a talk with Lou about this, and said that in my opinion one can be a good biologist without feeling much about physiology, but admitted that one must have worked in physiology for his doctoral exam. In the meantime, I pointed out to Mrs. B. that her expressions are not very parliamentary and that one should not say everything as one thinks.

Plant Physiologists at the 6th International Botanical Congress at Amsterdam (1935). Baas Becking seated on a chair on the far left of the photo.

Although there was hardly any money available for architectural and constructional changes in the Laboratory, Baas Becking managed, partly due to his good contacts in The Hague, to realise these by employing unemployed workers. Under the tight budgetary curtailments of the 1930s, a reorganisation took place not only in the Laboratory and the Hortus, but also the teaching programme, in which the assistants as well as the technical personnel and students played an active part. He also succeeded in building a new greenhouse complex in the Hortus with a laboratory for plant physiological research, which replaced the old ramshackle hot-houses, whilst the historical Orangerie was also restored to its full glory. In 1938 The *Hortus Academicus Lugdunio-Batavus 1587-1937* was published, the history of the Leiden Hortus Botanicus. Against the custom of the time, Hero Veendorp, the hortulanus [keeper of the garden], was the first author and Baas Becking his co-author.

In the fourteen years, that he spent in Leiden, there appeared at least twenty publications from himself or co-authored with his students. Also, seventeen dissertations were completed on topics as diverse as microbiology, biochemistry, photosynthesis, protoplasmatics, salt biology and the mathematical analysis of biological processes. His own work was mainly concerned with microorganisms in saline environments. This was a continuation of his work in America. In the late 1920s he and his Stanford colleagues annually took trips at the end of the dry season to the salt lakes of Utah and the Sierra Nevada. In November 1928, they conducted research in Utah lakes where, according to Baas Becking's colleague Peirce, "Organisms are alive that should not be." From 1929 on, these excursions were pursued with laboratory experiments together with C.B. van Niel.[19] In Chapter X *Brine* in *Geobiologie* (1934) Baas Becking summarised his findings. Aharon Oren (2011) gave an introduction to Baas Becking's halophylic world.

On July 24, 1935, Baas Becking's teacher, friend and mentor F.A.F.C. Went died. After his retirement in 1933, Baas Becking had arranged an extraordinary chair for Went in Leiden. Went still held his oration, but no longer lectured due to his death. In August 1935 Baas Becking wrote a short in memoriam in the *Vakblad voor Biologen* in which he wrote in a solemn tone that "a great light is extinguished, but not until it has lit many lights."

That summer the 6th International Botanical Congress was organised in Amsterdam. Baas Becking gave a lecture about the freshening of the Zuiderzee, a brackish branch of the North Sea that was separated from the sea in 1932 by a 32 km long dam [Afsluitdijk]. His talk was a review of the biological changes and was mainly based on research of other scientists. He also read a paper *Halophytes and Antagonism*, a phenomenon that was later also discussed in *Geobiology*.

December 24, 1935, the Dutch Senate agreed to naturalise Baas Becking. Although senator N.Ch. de Gijzelaar criticised the government's naturalisation policy, he explained: "Now it is impossible, in my opinion, not to naturalise Prof. Baas Becking; it would not only be grossly unfair, but would be a major disadvantage to the honour of our country and to science in our country."

From February till September 1936, he took, with the fisheries biologist dr. J. Reuter, a study trip to the salterns of Bombay (India), the salt lakes in South Australia, the hot springs and volcanic waters of Madura and East and West Java (Indonesia) and the salt work Alagamento do Horta, near Praias (Portugal). In 1938 he wrote a short report of his journey in the *Proceedings of the Royal Netherlands Society of Sciences* and in *Geobiology* (1953) he described the lakes in Chapter IV *Water* in great detail in three paragraphs, which read like a travel journal. In addition, he made a report about the Australian salt lakes that he and Reuter visited, the commissioner of which is unknown. For the Dutch East Indies government, they also drew up an advisory report about salt production in Madura, "in which a method of biological cleaning of the brine was proposed", and later applied.[20]

's Lands Plantentuin Buitenzorg (1939-1940)

The visit became a turning point in his life. The country, as well as the scientific research done there and the enormous working area made a deep impression on him. In May 1936 in Buitenzorg he was consulted about the future of the Botanic Garden and its institutes by the Director of the Department of Economic Affairs. He submitted a report *Over de beteekenis van 's Lands Plantentuin* (1936) [*On the Significance of the Buitenzorg Botanic Garden*]. His approach agreed with Koningsberger's opinion on a more practice oriented role of the institutes.

19 C.B. van Niel (1932). On the morphology and physiology of the purple and green sulphur bacteria. On page 17 Van Niel expressed his gratitude to Baas Becking, "who enabled me to study the occurrence of purple sulphur bacteria in brines and salt samples from the Leslie Salt Works, San Mateo, Calif., from Searles Lake, Owen's Lake and Great Salt Lake".

20 The manuscript of Baas Becking's survey of Australian salt lakes was among the papers of his son Dick Baas Becking. A transcript is in possession of the author. *Kort Overzicht van de Werkzaamheden door L.G.M. Baas Becking verricht voor de Nederlands Indische Regering en voor de Federale Interim-Regering* (1948). AAS Basser collection 043 nr. 152.

Moreover, it matched with ideas and plans for a new colonial science of his friend and former fellow student in Delft Huib van Mook, who became Director of Economic Affairs in 1937.

As early as March 1938, Dutch newspapers reported the rumour that Baas Becking had been asked to succeed Dr. K.W. Dammerman, Director of the Buitenzorg Botanic Garden. Six months later it was announced that he would temporarily go to Buitenzorg, retaining his Leiden academic chair. His task was to reorganise the institutions of the Botanic Garden and to coordinate the scientific research and facilities of the private experiment stations, thus promoting the exchange of people between the different institutions. Early in 1939, Baas Becking, his wife and their 7 year old daughter Davida Carolina ('Daya'), accompanied by Jacoba Ruinen as assistant, travelled to the East Indies. Two months later he was appointed acting Director of the Botanic Garden. Their sons Jan (16) and Dick (14) remained in Holland, but in November 1939, their parents sent them to the Dutch East Indies, because of the threat of war.

Andrew Goss described the role of Baas Becking in the reorganisation of biological research:[21] he wasted no time submitting his advice, which was in line with Van Mook's enlightened vision of colonial science. However, administrative follow through was not Baas Becking's strong suit. He did not like dealing with the officials, lecturing them instead on the importance of biology. Nonetheless Van Mook carried through with the reorganisation plans, dragging Baas Becking and everyone else along. According to Goss "Van Mook's vision of a technocratic Plantentuin" cut through the 'applied' *versus* the 'pure' dichotomy that had defined the debate about colonial science since the 1910s.[22] The institutes of the Botanic Garden had to become a coordinating body where it could pursue a true worldwide scientific policy.

The reorganisation plan was adopted by the *Volksraad* at the end of February 1940. Baas Becking was appointed Director of *'s Lands Plantentuin* for a period of five years. March 4, 1940, he left for the Netherlands for three months, to resign from his position in Leiden and to consult with the *Ondernemingsraad*, in which the companies of the private experimental stations in the Indies were united. His family remained in the director's building in Buitenzorg.

Second World War (1940-1945)

On April 24, 1940, Baas Becking held his farewell oration in Leiden, "arguing for a social awareness among naturalists, to feel responsible for the fruits of their labour and for the manufacture of all kinds of 'toys', which would be taken out of their hands anyway."[23] However, the consultation with the *Ondernemingsraad* May 7, 1940 was not successful, because it was feared that there would be interference by the Garden authorities in several areas that threatened the independence of the private companies. Through the research coordination, the task of private experiment stations would no longer be determined by them.[24]

Baas Becking was to return to the East Indies on May 10, 1940, but the German occupation of the Netherlands made this impossible. Therefore, he kept his post at the university. Baas Becking belonged to the group of 22 Leiden Professors who already on June 22, 1940, decided to form a small resistance group. The aim of the group was "to draw a line in order to give support to the others: the group tried to create a national awareness and attitude of resistance in matters concerning the university". That summer he tried to escape to England with his sailing boat, but he was unable to bring the small wooden boat to the coast. In October 1940 he again attempted to escape, this time with the secret agent Lodo van Hamel, who was dropped in the Netherlands in August 1940.[25] In September 1940 Baas Becking had received a message from London, "to continue his work in Java as soon as possible." Underground resistance workers brought him into contact with Van Hamel. The attempt to escape failed as well. The seaplane that was to pick up the refugees in the Frisian Tjeukemeer on October 13, could not land. They were arrested by the Dutch police, who handed them over to the German *Sicherheitsdienst*. The prisoners were transferred to the German prison in Scheveningen, 'Het Oranjehotel'. There Baas Becking stayed in solitary confinement in *Untersuchungshaft*. On April 9, 1941, he was released under parole. Lodo van Hamel was executed on June 16, 1941.

On May 9, 1941, his mother died in Dutch Bergen. The obituary calls her "our faithful Mother." He returned to Leiden, where the university had been closed by the German authorities on November 27, 1940, after Professor R.P. Cleveringa's speech on the forced dismissal of his Jewish former teacher Professor E. Meijers. The ban concerned lectures, examinations and practical courses of students. The staff remained in service. Baas Becking managed to transfer his students and assistants to other universities. April 28, 1942, the Professorial resistance group decided to resign collectively as a protest against the measures implemented by the Nazi regime. The same day, Baas Becking tendered his resignation. According to a colleague, Baas Becking was one of the 'diehards' of the resistance. He put pressure on his doubting colleagues, he visited the former rector magnificus A.W. Byvanck, who was "deathly pale, as if he had signed his death warrant." In the end, 58 out of 93 Professors and lecturers would resign. The reaction of the German authorities was fierce. 22 Professors "were honourably discharged" at their request from their positions as ordinary Professors at Leiden University with effect from June 1, 1942. In July and August however, most of them were arrested and taken as hostages to Sint-Michielsgestel. Baas Becking escaped from captivity. By the help of his friend the biochemist Henri G. Derx, he was put in charge of a research group at Unilever in Rotterdam that studied the preservation of fruit and vegetables by keeping them at low temperatures.

He had no fixed address, that also may have helped him to remain out of German captivity. The first two years of the war he lived with his sister-in-law Eliza Haverman-Pinke in Scheveningen, thereafter he regularly stayed in Leiden with biologist and friend of the family Mrs. C.J. Niekerk-Blom ('Tine') and her four daughters, or with the De Jongh family in the Haarlemmerstraat. In Apeldoorn he used to

21 The summary of Baas Becking's role in the reorganisation of the Botanic Garden follows Andrew Goss (2011, p. 124-140, 2018, p. 209-213).

22 In December 1937 a lecture of Baas Becking about *Pure and Applied Science* was published in *Ceres*, the journal of the Wageningen Studenten Corps. He proposed that students of universities could prepare themselves for practice by spending some time working at an institute of applied science, while the students of an institute of applied sciences could broaden their scientific horizons by temporarily entering the university environment.

23 *Leidsch Dagblad* April 25, 1940, p. 6.

24 J. Sibinga Mulder (1943).

25 L. de Jong. *Het Koninkrijk der Nederlanden in de Tweede Wereldoorlog*. Deel IV (2^{e} band), p. 706-711; Deel 5 (1^{e} band), p. 77-80.

stay with Jeanne Teding van Berkhout-Tutein Nolthenius, whose husband, lieutenant colonel Jacob Johan Teding van Berkhout, a war hero, died in May 1944 in the Natzweiler concentration camp. Despite the danger of being arrested by the *Sicherheitsdienst* or to be betrayed by members of the Dutch NSB [Nazi party], he attended meetings of the Academy of Sciences in Amsterdam. He had been appointed Academy Member in 1935, in the vacancy caused by the death of Hugo de Vries. In October 1942, he delivered the Robert Mayer memorial lecture, on *Dissipation and Entropy*. At the end of November, he proposed in the general meeting of the Academy, to cease all activities in protest against the decision that Jews could no longer be members of the Academy. His proposal was defeated with 27 to 24 votes. He resigned; his friends and colleagues W.J. de Haas, Jan Hendrik Oort and Hans A. Kramers were the only Academy members to follow him.

Attempt to Escape to England and Creation of Geobiology (1944)

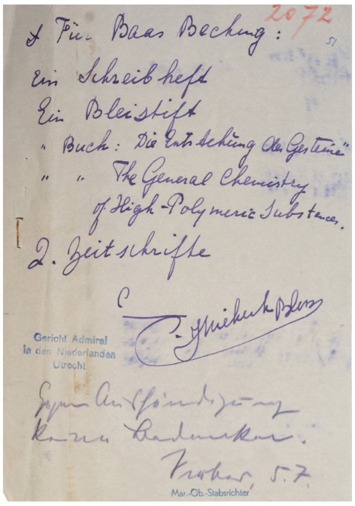
On April 26, 1944, Baas Becking and four fellow refugees, among whom the politician and former minister Professor Victor Rutgers, made an attempt to escape by boat to England.[26] They managed to make it 50 km out to sea at night when the engine failed. They were adrift for three days. On April 29 the boat had drifted to the Dutch coast off Schouwen. They were fired upon and later boarded by an armed trawler. All incriminating documents had been thrown overboard earlier. After having spent a few days in prison in Middelburg, Baas Becking was transported to Haaren, together with his fellow refugees. From May 15 until the end of June 1944 he was locked up together with three fellow refugees in a cell in Haaren as a prisoner of the German *Kriegsmarine*. Mrs. Niekerk-Blom was allowed "to bring him food and books, including the ledger, in which he then wrote down his thoughts on geobiology in pencil. I can never forget how he stood there next to the prison guard, touched but still tense and intensively listening and absorbing what he was told and understood in a language with twisted names."[27]

Apparently, she brought him the ledger in which he would write *Geobiology*. On the title page Baas Becking noted the date "April 1, 1944" and a dedication "to T.", most likely Tine Niekerk-Blom. The date suggests that Baas Becking had bought or received the notebook three weeks before his attempt to escape to England. In Haaren he had ink and a pen at his disposal, which he used to record the structure of *Geobiology* in the cashbook. He made a table of contents with 10 chapters, which were divided into 76 sections. For each section, he estimated the number of pages he thought he would need to fill the sections with text. He then divided the sections into the ledger by writing in ink the titles of the sections on the pages specified in the table of contents.

At the end of June 1944, the prisoners were "heavily handcuffed and transferred to the *Wehrmachtgefängnis* in Utrecht." Baas Becking and Rutgers were put in a neat cell. Sometimes there was a very long time for airing, and then they could smoke to their heart's content. July 5, 1944, was the first interrogation and the next day the session of the naval Court.[28] The sentence for him and his fellow prisoner Professor Rutgers was pronounced on July 6 and ratified on July 21, 1944, by the *Wehrmachtsbefehlhaber in den Niederlanden*:

> It is not necessary to elaborate on the fact that such attempts at unauthorised departure from the occupied Dutch territory must be prevented in these circumstances. The court therefore considered the amount of 2 years in prison for both defendants to be necessary. However, in view of their confession, it seems reasonable to credit the defendants Baas Becking and Rutgers with 2 months of pre-trial detention each.

The day before the trial, Mrs. Niekerk was in Utrecht. Baas Beckings *Personalakten* contains a receipt signed by Mrs. Niekerk on July 5, 1944 for the documents that she had brought with her for Baas Becking: "A notebook, a pencil, a book: *The Formation of Rocks*, a book *The General Chemistry of High Polymeric Substances*, 2 journals." *Marineoberstabsrichter* Karl Helmut Sieber wrote on the receipt, "Gegen Ausländischen keinen Bedenken" [No objection to foreigners]. The notebook was apparently the ledger, which Mrs Niekerk had given him earlier in Haaren. After he was transferred to Utrecht it was apparently sent back to her. On July 7, 1944, Mrs. Niekerk



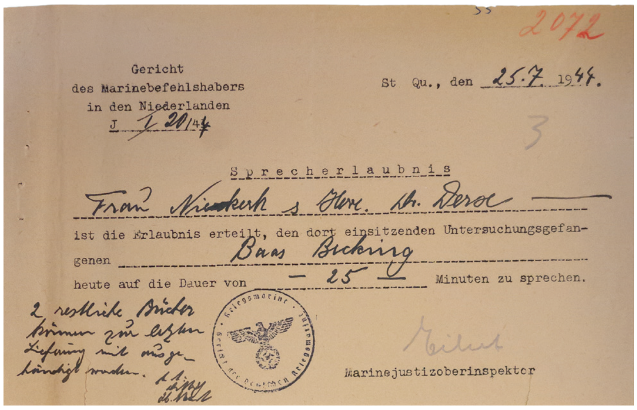
2072

Für Baas Becking:
Ein Schreibheft
Ein Bleistift
" Buch: Die Entstehung der Gesteine"
" " The General Chemistry of High-Polymeric Substances.
2. Zeitschrifte

C. Niekerk-Blom

Gericht Admiral in den Niederlanden Utrecht

Mar.-Ob.-Stabsrichter



2072

Gericht
des Marinebefehlshabers
in den Niederlanden
J 20/44

St Qu., den 25.7. 1944.

3

Sprecherlaubnis

Frau Niekerk u. Herr Dr. Derx

ist die Erlaubnis erteilt, den dort einsitzenden Untersuchungsgefangenen Baas Becking

heute auf die Dauer von 25 Minuten zu sprechen.

Marinejustizoberinspektor

Sprecherlaubnisse Kriegswehmachtsgefängnis Utrecht, July 1944, of Mrs. C.J. Niekerk-Blom and Dr. Henri Derx. Signed by Marineoberstabsrichter Karl Helmut Sieber. Institute for War, Holocaust and Genocide Studies (NIOD), Amsterdam.

26 http://www.hantjedejong.nl/verzet/engelandvaarders/. Thanks to Tjeerd de Jong for his information about the 'Engelandvaarders'.

27 Notes by Mrs. C.J. Niekerk-Blom, February 14, 1984. Collection A.J.P. Raat, Utrecht.

28 B. de Gaay Fortman (1946). *Levensbericht van Prof. mr. V.H. Rutgers*. Kampen.

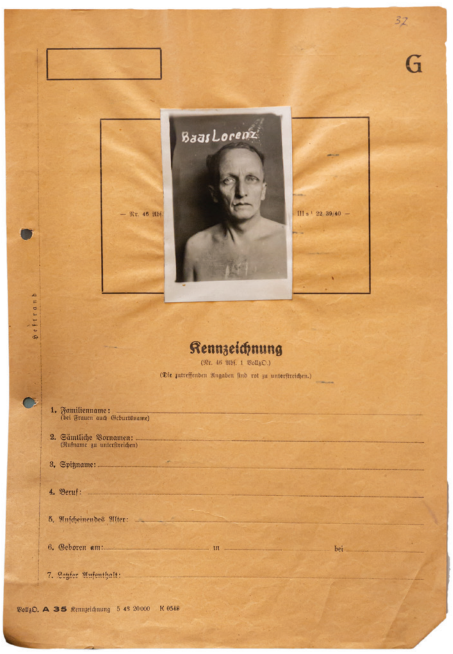
was given permission to speak to him for 15 minutes. In the following weeks she visited him twice, on July 25 (25 minutes) and on August 11 (30 minutes). On July 25 she was accompanied by Henri Derx. On the *Sprecherlaubnis* [Admission ticket] it is noted that two more books were handed over to Baas Becking.

On August 29, 1944, Baas Becking and Rutgers were taken handcuffed to the station in Utrecht. Rutgers was in "high spirits", joking and laughing throughout the trip to Cleves. The *Haftanstalt* in Kleve, Germany, served as a shelter for transported prisoners. There, in the courtyard, they saw each other for the last time on August 30. Victor Rutgers was put on transport to Bochum, to a prison that took in convicted Dutch people. He died there on February 5, 1945, as a result of ill treatment and poor health. Unlike Rutgers, Baas Becking was not transferred to a prison on August 30, 1944, but to the Siegburg *Zuchthaus* near Bonn, on the east side of the Rhine.[29]

In 1984 Mrs. Niekerk remembered that when Baas Becking was transferred to Siegburg, his books, "including the manuscript Geobiology", were sent to her by Sieber. "I copied the writing entirely by hand, because I thought it was too valuable to exist in a copy." Baas Becking took this copy with him when he went to the Dutch East Indies in September 1945.

Siegburg (1944-1945)

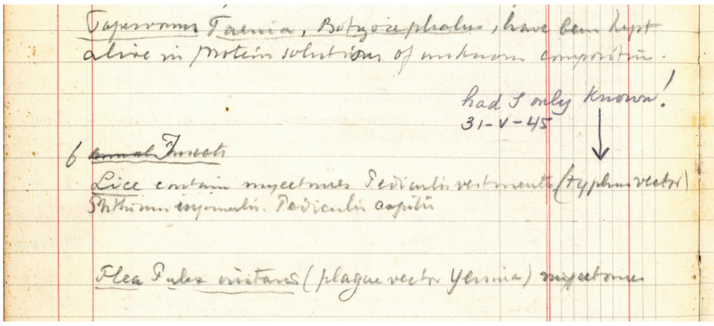
On October 30, 1944, he arrived in the German disciplinary centre Siegburg. He was registered and put to work as a nurse in the *Arbeitslager* of the *Rheinische Metallwerk* in Porz. Sometime later he was discharged, "because he refused to propose as 'fit to work' those comrades which were sick." Afterwards he did "the hardest labour in the factory (especially at night) until almost dying of neglect and heart trouble." In January 1945 he



Registration form Baas Becking, Zuchthaus Siegburg August 30, 1944. NIOD Amsterdam.

worked as a medic in the "so called hospital" of the Siegburg prison with the Dutch physician and fellow prisoner Fridjof B. Heberlein. He nearly died of typhus.

On April 10, 1945, the prisoners in Siegburg were liberated by the American 1st Army. Together with Dr. Heberlein he was put in charge of the Displaced Persons Camp until May 25, 1945, when he was repatriated to the Leiden Elisabeth Hospital. However, neither his position as head of the DP Camp nor the effects of the typhus epidemic prevented Baas Becking from compiling a report, *The Typhus Epidemic at Siegburg Penitentiary in 1945*, during the five weeks of quarantine, which described the miserable conditions in the penitentiary.[30] According to the *Typhus Epidemic* report, on a population of 1,920, persons in the period January 1 till May 25, 1945, 1,081 (56 %) were infected and 281 (15 %) died. On 30 May 1945, he wrote in the Leiden hospital in his manuscript of *Geobiology*, after his earlier note on the spread of typhus: "Had I only known!"



Return to The Dutch East Indies (1945)

It is likely that Baas Becking had decided in 1943 to return after the war to Buitenzorg and give up his Professorship in Leiden. In a letter to his colleague the zoologist C.J. van der Klaauw he wrote: "I had better go. I will go too. Without any bitterness or resentment or hurt. If I am not present, you will feel freer. The world is big enough for me." Van der Klaauw had told Baas Becking that it had been "more pleasant" for him and his colleagues Lam and Boschma, when he was in the Dutch East Indies.[31] Another argument to leave Leiden was that in 1945 he was dissatisfied with the lenient treatment of his collaborating colleagues. He demanded stricter sanctions and was "fierce and wanted to hang all weaklings", according to Professor van Arkel. Another colleague characterised Baas Becking afterwards as, "a very fascinating figure, a great organiser, with far reaching hobbies and a great urge to expand, but he no longer fitted in here."[32]

After a few weeks' stay in the hospital, he received a telegraphic request from the Lieutenant Governor-General Van Mook "to go immediately to Java in the service of Evacuation of Prisoners of War and Civilian Internees." On September 10, 1945, he flew as a colonel of the *Royal Netherlands-Indies Army* (KNIL) from Brentwood in Essex to the Allied headquarters of the *South East Asia Command* (S.E.A.C.) in Ceylon. As an officer of the *Recovery of Allied Prisoners of War and Internees* (RAPWI) service, he travelled with the Dutch troop ship *Plancius* to Priok. There he arrived on October 2, 1945. His 20 year old son Dick, who had been

29 NIOD 214 nr. 33, *Personalakten* Siegburg Baas Becking, August 30, 1944.
30 NIOD 250c, nr. 167. L.G.M. Baas Becking, editor. *The Typhus Epidemic at Siegburg Penitentiary in 1945.*
31 Museum Boerhaave, correspondence Baas Becking and C.J. van der Klaauw.
32 Archive J.A.F. de Jongste, Academisch Historisch Museum Leiden, Professor P.A.H de Boer February and March 1965.

during the Japanese occupation for three years an inmate of the boy's camp Tjimahi, described how he saw his father again, after an absence of five and a half years: "3 October: Colonel L.G.M. Baas Becking runs into his stunned son in Tjideng! Father is completely O.K.!!!!! 4. October: I go with father to the "Plancius", where the head of the Int. Red Cross, section Netherlands, admits me to this honourable institution and, in spite of my vehement protests, gives me the rank of sergeant. 5. October: I arrive at the military hospital and am put to work in the laboratory."[33]

Baas Becking's Family

Baas Becking's wife Rabina and his 15 year old daughter Daya were at that time in the Tjideng hospital. They spent the years of the Japanese occupation in several womens camps. In her autobiography Daya described the cruelty of the sadistic captain Kenichi Sonei, the hunger and the diseases.[34] Her account evokes admiration for her mother Rabina, who despite her poor health was an example of stability for her daughter and her fellow prisoners. September 9, 1945, Rabina heard that her son Jan Matthias had died of "pellagra" on April 4, 1945, in the Mariso prisoner of war camp, south of Makassar (Sulawesi). Two days later Dick received a desperate letter from his sister that their mother was in the hospital with severe jaundice, she weighed 32 kg. Dick was discharged from the Tjimahi camp and travelled with 16 boys in a train carriage of the Japanese military police to Batavia. In November 1945 Rabina weighed 38.1 kg. In December 1945 she repatriated with her son and daughter on the ship *Oranje* to the Netherlands.

Baas Becking remained on Java, giving priority to his work as head of the RAPWI mobile teams. In May 1946, during a short stay to recruit nurses in The Netherlands, he gave a lecture entitled *What Women have done and can still do in the East Indies.*[35] The speech, which is couched in swollen, patronising words, reads like a failed attempt to share his family's wartime experience in the East Indies. It is not very convincing: emotions expressed in empty terms. In doing so, he unintentionally and in a shrill and tragic way, demonstrated the emotional distance that had been created between him and his family by their war experiences. The mutual sharing of the traumatic war events was apparently not possible. In December 1946, Rabina in Leiden described their family friend Huib van Mook, at that time the highest authority in the Dutch Indies, the isolation in which she and her husband found themselves:

> After all those years of not seeing Lou, and then hardly seeing him, I increasingly feel that being with him might help with his work. Indirectly, of course, and not at all scientifically, but as a kind of blockade against excessive aspirations and excessive wild ideas, or like a clothes brush smoothing its feathers, or a gramophone record repeating "come, come" and "tut, tut." In clearer words, I love him (perhaps) too much - in any case I am sorry that he confuses and stifles himself with impatience in his many talents. Huib, if you think this is worthwhile and if you have confidence in me in this respect, could/will you give me permission to go to Buitenzorg.[36]

In 1947 she was for some time in Buitenzorg, but returned to Holland and rented a house in Bilthoven where she lived with Daya until June 1949 when they came with him to Noumea.

Chairman Coordination Committee Scientific Research 1945-1946

Upon his return in Batavia Baas Becking took up the coordination of the agricultural, veterinary, chemical research institutes, experimental stations and laboratories, although the coordination committee was not earlier officially installed than in March 1946.[37] Many institutions were after the Japanese period partly destroyed or plundered, personnel were traumatised or died in camps. At Java institutes and experimental stations were in Republican territory and inaccessible to the Dutch personnel. In a first meeting early December 1945, the agenda items were the temporary relocation of activities outside Java and the availability of skilled staff. [38] According to Baas Becking, "the scientific staff of all institutes should be subordinate to the coordinating body." His motivation was that the best scientific personnel were being bought out by the private sector: "Are we to help these people in scientific matters, which have the preconceived goal of not letting the results benefit the community?" For Baas Becking, the plan approved by the *Volksraad* in 1940 was the blueprint of his policy. In his actions he brushed aside the objections of the *Ondernemingsraad* in Holland in 1940. Without adequately informing the companies or the *Ondernemingsbond*, the Indian counterpart of the *Ondernemingsraad*, he visited private experimental stations and promised employees scholarships for training abroad. In March 1946 there was a meeting of the *Ondernemingsbond* with deputy Governor-General Van Mook, in which Baas Becking's interference in the private experimental stations was indignantly rejected: "We did not call him, but Koningsberger, because he is better on this point." His defense was, that his intention had always been to provide "service." He was convinced that "he had been working for the common good."[39] Victor Koningsberger arrived in July 1946 for a period of 4 months as a representative of the private sugar companies. During his mission he ensured better relations between the Dutch-Indies government and the private sector.[40] This virtually ended Baas Becking's role in coordinating scientific research in the Dutch East Indies. In 1947 he was no longer chairman, but a member of the committee.

RAPWI Mobile Teams (1945-1946)

Early 1946 Baas Becking also set up the first Medical Inspection and Mobile Team, working under the auspices of the RAPWI. His activities in 1946 were focused almost exclusively on the

33 Undated letter, November 1945 Batavia, Dick Baas Becking to unknown friend 'Jan'. Private collection.
34 Teding van Berkhout, Daya (2010), p. 27-53.
35 Typescript lecture by L.G.M. Baas Becking 23 mei 1946. ATRIA Archief Willemijn Hendrika Posthumus-van der Goot 1896-1988. Nr. 14. 1946. Thanks to Marjet Denijs.
36 NA 2.21.123 Collectie H.J. van Mook 176 nr. 372, Letter Rabina Baas Becking-Haverman to Huib van Mook, Leiden Witte Singel 30, 16 Dec[ember] [19]46.
37 NA 2.20.34 nr. 206. Official decision establishing the Commission is dated March 21, 1946. On March 10, 1946 Baas Becking gave a speech *Coordination of the Sciences*, as official start of the Committee. NA 2020.34 nr. 262.
38 NA 2.20.34 nr 249, report of meeting December 5, 1945 in Baas Becking's room.
39 NA 2.20.34 nr 206, report of meeting March 9, 1946 in the palace of the lieutenant Governor-General H. van Mook.
40 See Coen Görts (2014). Victor Koningsberger 1895-1966. De hoogleraar die zijn rug recht hield. Matrijs, Utrecht, p. 91-104.

mobile teams, which intended to provide outpatient health care for the indigenous population. By mid-February 1946, he had formed a small organisation of volunteers. The teams were working in the area controlled by the Republik Indonesia. During a stay of a Dutch parliamentary commission in April 1946, Baas Becking made his 59th journey there: "He was always received with open arms, by the extremists included, who apparently gratefully accepted good nursing, even from Dutch people."[41] Since April 1946, Baas Becking's teams worked together with the Netherlands Red Cross in Indonesia. Cooperation with the Red Cross however, was difficult, because he interfered with food distribution and everything the Red Cross had to do with. He was known as a troublemaker, but he was appreciated by his military team. Victor Koningsberger spoke in September 1946 about "the passion and bravery with which my colleague Baas Becking organised and led the mobile teams." The outpatient clinics of the mobile teams, at its peak sixteen, were visited between March 1946 and March 1948 by 2,500,000 people, who underwent approximately 3,500,000 treatments.[42] As of January 1, 1947, he was relieved of his duties by Van Mook, probably because of the recurring disagreements with the Red Cross workers, but also because he neglected his duties in the Botanic Garden at Buitenzorg. However, he remained a member of the board of the Dutch Red Cross, section Indonesia, until October 1948. In July 1947 he wrote to physicist and philosopher Professor J. Clay in Amsterdam: "You know that the Dutch East Indies government looked with sorrow at all my social and coordinating work and that Buitenzorg was actually a kind of penal garrison for me."[43]

Botanic Garden Buitenzorg (1947-1948)

After the Japanese attack on the American marine bases at Pearl Harbor, December 7, 1941, most of the Dutch staff members of the Garden institutes were registered as military. In March 1942 the Japanese invaded Java, the Botanic Garden came under Japanese control. The Japanese had strict orders to leave Buitenzorg intact. The Botanic Garden was given a Japanese management of professional botanists, who ensured that some of the Dutch scientists, who were held as prisoners of war, could return to Buitenzorg. The plant taxonomist Kees van Steenis and his wife were allowed to work during the day in the Herbarium; each night Kees stayed in the POW camp outside the Buitenzorg Botanic Garden. Jacoba Ruinen also remained in Buitenzorg, she worked in the Treub Laboratory and acted as a liaison for the wives and children who were imprisoned in the women camps.[44]

After the Japanese surrender, August 15, 1945, the Botanical Garden complex lay in Indonesian Republican territory. In December Buitenzorg came under control of the British army, but a part of the institutes remained under Republican control. Baas Becking was mostly absent due to his RAPWI work. Kees van Steenis took care of his duties, through intensive contact with the English brigade commander and support from staff members.[45] This did not prevent that valuable material was destroyed and theft and plundering of the institutions continued. In November 1946, Buitenzorg came under Dutch military control, but an attempt to bring all the institutes under Dutch control failed, because the government in Batavia forbade it.

*Staff of the Buitenzorg Botanic Garden (Java), December 1947. **From left to right**: Mrs. M.C. Vreede (Treub lab.), Mrs. E. Bakker-Beer, C.L.L.H. van Woerden (hortulanus), Dr. M.A. Donk (mycologist), Dr. M.A. Lieftink (entomologist), unknown, Dr. B. Hubert, Dr. A. Diakonoff (entomologist), Dr. R. Sinia, Dr.Ir. H.G. Derx (Treub lab.), Dr. J.D.F. Hardenberg (fishery biologist), unknown, Rabina Baas Becking-Haverman, Dr. A.C.V. van Bemmel (zoologist), Lourens G.M. Baas Becking, Dr. L. van der Pijl (botanist), Dr. K.B. Boedijn (mycologist), Dr. J. Reuter (zoologist), Mr Bakker (FAO), Dr J.A. Frahm-Leliveld (cytologist), Dr. M.A. van Raalte (plant physiologist), Dr. J. van der Vecht (plant pathologist), Dr. S. Bloembergen (botanist), Dr. L.J. Toxopeus (entomologist), Dr. L.C.P. Kerling (mycologist), Dr. K.F. Vaas (fishery biologist). Photo Tropenmuseum (NMvW) Amsterdam, inventarisnummer: ALB-2210.*

41 Verslag Parlementaire Commissie Nederlandsch-Indië, 1 mei 1946, Bijlage 208. 2 Tweede Kamer.

42 L. van Bergen (1996). Een onmisbare schakel. Het Rode Kruis in Indonesie (1945-1950). *Militaire spectator* 165, 6-96 (p. 269-277, see p. 270).

43 Letter L.G.M. Baas Becking to Prof Dr. J. Clay, Amsterdam. 's Lands Plantentuin Buitenzorg, 16 juli 1947, Archive Museum Boerhaave Leiden.

44 Invaluable sources are M.J. van Steenis-Kruseman (1990). *Verwerkt Indisch Verleden.* Oegstgeest and the Autobiography of Baas Beckings daughter Daya: Teding van Berkhout, Daya (2010). *When I was… An Autobiography.* Echo Books, Australia.

45 NA 2.20.34 nr. 234. Typescript Dr. C.G.G.J. van Steenis, *Report on the State of the Scientific Institutes Buitenzorg.* January 1946.

Andrew Goss gave a short summary of Baas Becking return in 1947 in Buitenzorg as director of the Garden and its institutes: "He tried to take up where he had left off in 1940".[46] This is also evident in his oration *The Buitenzorg Botanic Gardens and Community*, held May 18, 1947, in which he claimed that "the structure proposed for these institutes in 1940 […] has not been disturbed and is still present in the spirit of virtually everyone." However, he miscalculated the spirit and political developments. He stuck to exalted ideas of the position of Buitenzorg as an international scientific centre: "Our problem is no problem of race or nation. We only have to respect the dignity of science and to take good care that only competent authorities preside over it. Because the responsibility we have to bear is too great to allow any dabbling with the international academic status of the workers for extraneous reasons. And the whole world will certainly agree with this aim."[47] The competent authorities and workers he referred to, were the all white staff of the Buitenzorg Botanic Garden, as can be seen on the photo that was made in December 1947.

He was making no serious effort to recruit new Indonesian scientific personnel, because "the Indonesians cannot yet stand on their own two feet."[48] Moreover, in 1946, Mrs. Niekerk, as an honorary external secretary of the coordination committee in Leiden, recruited Dutch scientific personnel for Buitenzorg.[49] In this context his words in the oration: "To our Indonesian friends we are exclaiming: 'Let us join forces'. Let us not deliberate too long, let us arrive at deeds", come across as insincere and implausible. Personally, Baas Becking favoured a highly unrealistic *International and Internationalised Centre of Tropical Research* at Buitenzorg. In a confidential document he described an international protectorate of 10,000 km^2 under control of the United Nations, "with its own government and its own police", and "an open emphasis upon the impartiality of sciences."[50]

In July 1947 after a major military offensive ('first police action'), all institutes of the Botanic Garden came under Dutch control. The Dutch newspaper *Het Parool* reported September 4, 1947:

> In Buitenzorg, heavy pressure is being exerted to get the civil servants to resume work. Prof. Baas Becking, director of the Botanic Garden in Buitenzorg, played a particularly active role in this. He threatened his staff with expatriation to Bantam and claimed that this was a general government order. "We ignore government orders that do not suit us", said Mr. Baas Becking literally. "There is no question that I have to obey the central authority. For two years I have always been one step ahead of the government, afterwards they always agree. When there is talk in Batavia, there must be men who persevere."

It demonstrates Baas Becking's lack of diplomatic tact, which made him unfit to run the Botanic Garden under the Indonesian Republican authority after 1949. He resigned when he was informed, that he could only stay after the expiry of his contract in October 1948, under the condition that he "devoted himself entirely to his scientific work."[51]

Deputy Chairman Research Council South Pacific Commission

Baas Becking's deputy chairmanship of the Research Council of the South Pacific Commission (SPC) is another tragical intermezzo in his personal life and professional career. At the Second Session of the commission in Sydney in October 1948, the commission unanimously decided to offer him the appointment, which he accepted October 28, 1948. The commission was "a consultive and advisory body on matters affecting the welfare of the peoples of the non-self governing territories in the South Pacific." Baas Becking defined the role of the research council as "relating to the economic development, social development and hygiene of the area."[52] It had its headquarters in Noumea, French New Caledonia.

From February to mid-April 1949 Baas Becking and the three full time members of the research council, visited New Zealand, Fiji, Western and Eastern Samoa, Dutch and Papua New Guinea and Australia. They consulted authorities, organisations and specialists. Schools and hospitals were visited. In his opening address, at the first meeting of the research council in Noumea on April 30, 1949, he asked the question, "What is the role of the white man in this region?" He mentioned the importance of independent science for the implementation of practical measures. The core of his view was that culture cannot be transplanted, for its roots are too deep in history: "Civilisation is the material expression of culture. We have therefore to ask ourselves: which are the elements of Western civilisation that can be grafted upon existing local culture in order that the happiness of the natives may be promoted?" Thus, his answer to the question was Eurocentric and recalls the Dutch Ethical Policy for the welfare of its colonial subjects. He called the mission of his research council a "superannuated 'mission civilisatrice.'"

In Noumea however, the romance of international diplomacy and the lofty academic perspectives, were in shrill contrast with the daily reality. He was the manager of a team of eight geographically dispersed persons, in a bureaucratic organisation with small budget, on a faraway tiny island in the Pacific Ocean. There, Baas Becking's visionary ideals gave way to the sadness of "intellectual starvation". In July 1949 he wrote: "There are a number of things that bother me a lot here. The main thing is that I cannot do any research myself and that I am only allowed to administer. That's not for me. I believe it is better that I look for another job (July 26, 1949)."[53]

In July 1949 his wife Rabina and daughter Daya arrived at Noumea. They settled in a Quonset hut, left by the Americans after the war, situated in a coconut grove opposite the beach. August 27, 1949, Rabina stood near the

46 Goss (2011, p. 136).

47 Manuscript *The Buitenzorg Botanic Gardens and Community.* Oration of Prof. Dr. L.G.M. Baas Becking on the 18th of May 1947 to commemorate its 136th anniversary. Private collection.

48 NA 2.20.34 nr 249, report of meeting December 5, 1945, in Baas Becking's room.

49 NA 2.20.34 Indisch Comité Wetenschappelijk Onderzoek Natuurwetenschap (ICWO) en aanverwante archieven.

50 Document in Leiden University Library H1299. Apparently, the document was distributed to three persons, J.H. Statius Muller, resident of Buitenzorg 1946-1948, Professor E.O. van Baren, head of the Soil Science Institute and a third person who could not be identified.

51 Typescript *Kort Overzicht ban de Werkzaamheden door L.G.M. Baas Becking verricht voor de Nederlans Indische Regering en voor de federale interim-regering.* AAS Basser collection MS 043 nr 152; also private collection.

52 Baas Becking (1949). *Opening address by the Deputy Chairman International South Pacific Commission.* Manuscripts AAS Basser collection Ms 043, nrs 159, 160 and 161.

53 NA 2.21.2777 nr 9. Letter L.G.M. Baas Becking to resident of Dutch New Guinea J.P.K. van Eechoud. Noumea July 26, 1949.

front wall of the Quonset hut when Daya, with her father as her instructor in the seat next to her, put their new deep red Willys Jeepster into the first gear. The car went straight into her mother. Rabina died one day later. Baas Becking wrote to the Van Mook family: "Bine hardly suffered at all. She was given morphine after only four minutes. We are now going on a long journey to Sydney, Brisbane, Melbourne, Adelaide and then Oakland. I had to do it anyway in November. […] We are still too dull to realise anything."[54]

Returned from the trip to Australia in November 1949, the British senior commissioner of SPC, Sir Brian Freeston, interfered with his presence at the International Botanical Congress in Stockholm in 1950, as not "in the interest of the non-self governing *etcetera*'s."[55] William Douglass Forsyth, the secretary-general of the commission, told Baas Becking that he had to pay for the trip himself: "This means that I cannot buy a van and have to save for Daya and for myself to go to Dick's wedding." He had to cancel the journey and did not attend the Congress and the marriage of his son Dick with Solvig de Sitter in Leiden. In February 1950 the relationship with Forsyth worsened: "Now I have honestly tried to enter into a partnership with the secretary-general, but his statement, immediately following my offer, was that of complete supremacy of the secretariat. Now, if this really is a question of the personalities, I think it must be unfortunate if we would make the commission unpopular by internal disagreements." One month later he decided to resign, "In order to prevent all harm to the commission, because of my physical condition, which is not brilliant." Daya opposed all these plans, "chiefly because she wants me to make this a success. But I feel that I cannot do much good here anymore."[56]

Lourens G.M. Baas Becking circa *1955. Photo by H. Schenkel.*

Senior Scientist in Australia (1950-1963)

In September 1950 Baas Becking resigned as deputy chairman of the research council. After his decision to leave the council, his network of friends and colleagues helped him. In America, he enquired with his friends Frans Verdoorn and Frits Went, the son of his former mentor in Utrecht, but eventually he preferred to go to Australia. A return to the Netherlands was no option for him. In October 1950 he was asked by the Dutch Government for a study to set up a biological station for pure scientific research in Dutch New Guinea. He accepted the assignment, but because he found a position in Sydney, he did not conduct the study.[57]

In September 1950 Alan Burges, Professor of Botany at the University of Sydney, offered him an honorary research Professorship in the Department of Botany, which he accepted. In 1951 and 1952 he gave two courses for first year students, each of six weeks.[58] His notes and drafts of the lectures are preserved in the Adolph Basser Library Manuscript Collection of the Australian Academy of Science in Canberra. His experimental work for the university, on the effect of herbicides on plant growth, was paid by *Timbrol industrial and fine chemicals*. *Timbrol* paid him and two assistants 2,500 Australian dollars *per* year.[59]

In December 1950 he recommended *Timbrol* to include Franz Moewus in the Team.[60] Moewus and his wife Liselotte had arrived in November 1950 in the Botany Department of Sydney University. In the manuscript of *Geobiology* (1953) Baas Becking referred with admiration to Moewus's controversial experiments: "If one has had the privilege, like the author, to see Frans Moewus performing *Chlamydomonas*, one is amazed at the complexity of the behaviour of these unicellular algae and of the physical and chemical factors controlling their various coordination's with the environment." Moewus and his wife joined the staff of the Botany Department as Timbrol research fellows. When he left the Timbrol Team in February 1953, Baas Becking wrote his former employer: "I feel that herbicide research still holds many mysteries, and I have to congratulate you upon the furthering of the work

54 See Daya's account in Teding van Berkhout (2010), p. 61-62. In the Van Mook collection in the National Archive, The Hague, there is a letter written by Daya Baas Becking and her father to the Van Mook family. Noumea August 31, 1949. NA 2.21.123 collectie H.J. van Mook 176 nr. 372.

55 Baas Becking was invited to act as Chairman for the Commission for Botanical Stations by Frans Verdoorn, June 10, 1949. After consulting the secretary general of SPC, Baas Becking accepted the invitation on July 9, 1949, under provision that the commissioners of SPC were informed.

56 See for the letters quoted in this paragraph Digital Library Adelaide. H.E. Maude Part I, Series J., Sections 23 and 24. Letters Baas Becking to Henry Evans Maude (1906-2006), anthropologist, Deputy Chairman SPC and full time member research council SPC. Letters December 9 and 13, 1949, February 16, and March 10, 1950.

57 NA 2.10.54 nr. 4291. Letter Prof. Dr. M.W. Woerdeman, KNAW July 10, 1950. Telegram Baas Becking Noumea. Mail message ministry Uniezaken en Overzeese Rijksdelen, November 6, 1950.

58 AAS Basser collection Ms 043 nr. 152. University of Sydney November 6, 1951, and December 5, 1952.

59 AAS Basser collection Ms 043 nr 161, letter Alan Burges to Baas Becking, Sydney, September 29, 1950.

60 AAS Basser collection Ms 043 nr. 152. Letter 21 December 1950, Timbrol to Baas Becking. For Franz Moewus see Jan Sapp (1990), *Where the Truth Lies*, p. 210-212.

of Dr. F. Moewus and Mrs. L. Moewus. We all feel that the presence of these excellent biologists should not fail to be of great influence on the scientific development of this research."

In 1953 the Fisheries Laboratory of Commonwealth Scientific and Industrial Research Organisation (CSIRO) offered him a research position as a hydro-biologist ("senior fellowship") in Cronulla, New South Wales. To Mrs. Niekerk in Leiden he confessed: "It is a 'young man's job' and I can do it as long or short as I like, but 'I got to pay the butcher and the baker.'"[61] There his research dealt with the microbial origin of the sulphur nodules in Lake Eyre.[62] He also published with D. Moore and I.R. Kaplan a series of nine articles (1955-1957) on biological processes in estuarine environments, in the *Proceedings* of the Royal Academy of Sciences.

He worked in the Division of Fisheries at CSIRO until 1957, then he moved to the Bureau of Mineral Resources in Canberra to concentrate upon the part that microorganisms might play in the syngenetic deposition of minerals. During his last three years this became a joint research project supported by the Australian Mining Industry Research Association as well as the Bureau of Mineral Resources and CSIRO. Baas Becking moved his laboratory to the Division of Plant Industry in CSIRO Canberra, where he worked in close collaboration with Dr. John Falk. Here he was able to pursue further some of the imaginative ideas which he always had. In August and September 1959, he was active as a field researcher in Papua New Guinea, where he studied, with volcanologist G.A. Taylor, the volcanic waters in New Britain. There he realised that it was "a privilege to be a naturalist."[63] His detailed geothermal observations and beautiful sketches of the active volcano Tavurvur and the environments of Rabaul, Talasea, Pangulu and the island of Lolobau, are kept in the Adolph Basser Library collection of the Australian Academy of Science.[64]

November 1948 was the last time Baas Becking visited the Netherlands. In 1956 his friends and colleagues invited him for a lecture tour in Holland and the United States.[65] However, his poor health and perhaps feelings of resentment, withheld him. In his personal papers there are notes for short stories that give an idea of both his penchant to the romantic and also of his turbulent and gloomy state of mind. A romanticised memory of the five year old Lou in his grandparent's doctor's house in Veenendaal, is a charming short story. *Grandfather's House* describes his mother's Berkhout family and contains many autobiographical elements, probably partly taken from the stories of his mother. Other notes concern a futuristic novel *Zero minus Five*, in which celestials are in contact with humans. It is a bitter even cynical reflection on humanity of a disappointed solitary man.

The last years of his life Baas Becking had serious health problems. In 1960, after his stay in New Britain, he underwent surgery for a non-malignant tumour on the bladder. He had also problems with his heart. Later he suffered an attack that made it impossible for him to speak. Nevertheless, he remained active as a researcher. In the Library of the Australian Academy of Science there are many notes for a book on water for Elsevier Publishing Co. In August 1961 however, he felt "the load is somewhat heavy", and therefore suggested his former collaborators Ian P. Kaplan and Derek Moore, that they join in the publishing of the book. With his death one and a half year later however, this project ended.[66]

Since he lived in Cronulla, Baas Becking was taken care of by his housekeeper, Mrs. Ennie Bombeeck, who married him, according to his daughter Daya, "at his insistence", in 1961. He died in Canberra January 6, 1963.

In 1965 John F. Falk, of the CSIRO Division of Plant Industry, wrote Dick Baas Becking that "a research group on biological influences in the formation of minerals, and related topics, following leads opened up by his father", was established in the new laboratory building of the Bureau of Mineral Resources in Canberra. The group was called "The L.G.M. Baas Becking Biogeological Research Group (or Laboratory)."[67]

61 Letter Baas Becking to Mrs. C.J. Niekerk-Blom, March 12, 1952. Private collection.

62 Baas Becking and Kaplan (1956).

63 Letter Baas Becking to A. Quispel, Canberra July 11, 1960. I am grateful to Anton Quispel's daughter, Joanna Quispel, for this information.

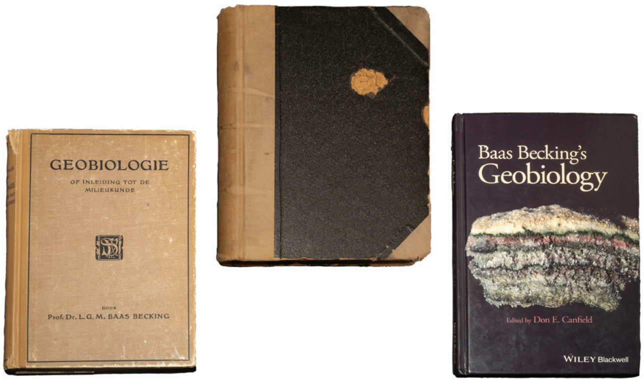
64 AAS Basser collection Ms 043 nr. 52.

65 AAS Basser collection Ms 043 nr. 151. Letters W.H. Arisz (Groningen December 21, 1955 and March 14, 1956), F.W. Went (Passadena, November 22, 1955 and February 1, 1956), B.D.J. Meeuse (Seattle, July 4, 1956).

66 For contacts in 1961 with Elsevier Publishing co. and Baas Becking's "Water book" see AAS Basser Collection Ms 043 nr 152. Letter Baas Becking to Norman Fisher, August 1, 1961, see AAS Basser collection 043 nr 1. December 9, 1962. Ian P. Kaplan wrote from Jerusalem that he met Derek Moore at Southampton. They decided "that the book should not be one dealing primarily with WATER but rather should be approached from the biogeochemical direction". Kaplan "should attempt to make a new outline incorporating Baas Becking's concepts". April 23, 1963, Ian Kaplan wrote from Jerusalem to John Falk a devastating and detailed review of the manuscript. "Most of it contains old concepts prevalent in the 1930's, such as on permeability for example. The text is largely descriptive. Quantitative data is either lacking, or in many cases badly documented and the original sources of the information are unknown, or his method of calculating is not clearly given". AAS Basser collection Ms 043 nr 24.

67 AAS Basser collection Ms 043 nr. 152. Letter J.E. Falk CSIRO to H.G. Baas Becking May 14, 1965.

THREE VERSIONS OF *GEOBIOLOGY*



History of the Manuscripts

In August 1951 Baas Becking wrote to his friend Frans Verdoorn, founder and editor of *Chronica Botanica* in Waltham (USA), about the history of his *Geobiologie* since 1934:

> The old book (a mere skit) of 1934 only gave a point of view. Since then, I have had considerable field experience, many Leyden students worked on problems connected with milieu, which we promptly buried either in the Recueil or in the Academy Proceedings. I have had a fine time in Leyden. I was happy there; I wish I could do justice to the work that was performed there by so many workers. There are reams of stuff that have remained unpublished. I had hoped to gather this material into a series of Essays on Geobiology.[68]

That *Geobiologie* should be seen as a brief comedy show, is an ironic characterisation. With "mere skit", Baas Becking probably referred to the laymen who attended his lectures on the "connection between organisms and the earth" for the Diligentia Society in The Hague where he entertained his audience in the winter 1933/34. No doubt Baas Becking took his task seriously. The role and responsibility of the biologist in society was a theme that had occupied him much longer. In 1928 he had written a polemical essay in *De Gids* in which he portrayed the gap between natural sciences and humanities as a contrast between "arguing Athenians in the marketplace and Boeotians with hand on the plough."[69] Lectures for a wider audience than just academics were a means for Baas Becking to bridge that gap and to emancipate his fellow scientists. One year before his lectures on geobiology in The Hague, Baas Becking and his colleague, the cultural historian Johan Huizinga, organised a lecture cycle *Worldview and Science around 1700* in the Leiden Botanical Laboratory. The evening lectures were also intended for a wide audience of students and other interested parties:

> To show to those who practice the humanities how natural science has become an integral part of our modern civilisation, and to those who practice natural science, how much that development in nature and direction was influenced by religious, philosophical and social currents.

In 1928 Baas Becking had agreed with a publisher to write a series of essays in which his Utrecht inaugural lecture would be further elaborated. However, he made no progress. In February 1930 he wrote confidentially to his mentor F.A.F.C. Went that he needed more time for a better understanding of "milieu". He explained: "More and more I come to the realisation that my specialty must lie in the field of the milieu; a modern ecology that has to take into account physical and chemical factors." A year later, in January 1931, he elaborated on milieu in his inaugural lecture *Gaia or Life and Earth.* Like his 1927 Utrecht inaugural address *On the Universality of Life,* he was inspired by Henderson (1913), Goldschmidt (1922), Vernadsky (1924) and Lotka (1924). Three years later in *Geobiologie*, he published his views still more expanded.

It was Baas Becking's ambition to transform *Geobiologie*, into a manual for an academic audience. According to Jacoba Ruinen, who worked in Leiden under his supervision on her PhD thesis (1933) and accompanied Baas Becking and his wife to Buitenzorg in 1939 as his assistant, "he had been working since 1933 on a more extensive and very detailed set-up of the thoughts developed in Geobiologie. A draft of several chapters with illustrations and tables accompanied him to Buitenzorg in 1939. However, this concept remained in its entirety behind in Indonesia when Baas Becking flew to the Netherlands in March 1940."[70] It was preserved in the Buitenzorg Botanic Garden during the Japanese occupation and used for his revision of *Geobiology* after the war in Indonesia and Australia.

During the war years that he was forced to spend in the Netherlands, Baas Becking kept to his intention to write a thorough scientific treatise on geobiology. In July and August 1944, within seven weeks in the *Kriefswehrmachtgefängnis* in Utrecht, he produced a manuscript *Geobiology*, "written in English because the author had to choose another language than Dutch to avoid duplication of work and because he had insufficient command of the German idiom." Unfortunately, there are no documents or schemes that illustrate how and when he prepared the framework of *Geobiology*: its division into 10 chapters and 76 sections and its further subdivision into paragraphs. The framework is characteristic for his top down approach of biological problems: coherence becomes clear when the total system in which that coherence takes place is broken down into smaller parts. In *Geobiology* this approach is demonstrated in the structure of all the chapters of the treatise. In its totality, *Geobiology* gives an impression of a work under construction whose foundation and structure are nevertheless clearly visible. Some of the paragraphs were completely filled in with text, while others only contained text fragments or keywords. Several paragraphs were only brought up by a heading.

Although Baas Becking wrote on the title page of the *Geobiology* manuscript "without the aid of literature", he had access to several books and probably the 1934 edition of *Geobiologie* and his own notes, which he had made during the preceding years in the Netherlands. The books mentioned on the receipt were Correns (1939). *Die Entstehung der Gesteine, ein Lehrbuch der Petrogenese* and Mark (1940). *The General Chemistry of High Polymeric Substances*. It is very probable

68 Letter Frans Verdoorn, Waltham to Baas Becking in Sydney, October 7, 1953. AAS Basser collection 043 nr. 116 Letters Chronica Botanica Company.

69 Baas Becking (1928) Atheners en Boeotiers. Een boutade en een apologie [Athenians and Boeotiers, A boutade and an apology]. According to Willem Otterspeer (2021, p. 488), "one of the best essays ever published by *De Gids*." It is the Dutch version of C.P. Snow's *The Two Cultures and the Scientific Revolution* (1959).

70 Letter Jacoba Ruinen to Professor H. Linskens, March 18, 1983. Baas Becking archive A. Raat, Utrecht. See also Linskens (1983).

that he also had Clarke (1916). *The Data of Geochemistry* at his disposal during his stay in the Utrecht prison. There are many references to Clarke in *Geobiology*. Baas Becking referred since his inaugural address in 1927 from the third edition of this handbook. *The Data of Geochemistry* remained an ever present source of information for him until the end of his life. Possibly he also could use Chibnall (1939). *Protein Metabolism in Plants*. In *Geobiology* he referred extensively to the research of Marie Antoinette van Overeem. Probably a copy of her thesis *On Green Organisms Occurring in the Lower Troposphere* (1937) was available.

After the war Baas Becking took a typescript of the hand written manuscript of *Geobiology*, made by Mrs. Niekerk-Blom after she received the handwritten manuscript from the German prison authority in Utrecht, to the Dutch East Indies in September 1945. There he worked on the revision of *Geobiology* in addition to his work as a RAPWI colonel organising Red Cross mobile medical teams in Java (until the end of 1946) and his directorate of the botanical garden in Buitenzorg (until December 1948). In November 1948 before his departure to French New Caledonia, he was for a short time in the Netherlands. He was quoted in the Dutch newspaper *Trouw*: "I am here with a government assignment, namely to finish my book on geobiology, based on field and laboratory research over the last 20 years."[71] The draft version of the revised and updated *Geobiology* was completed in Sydney in 1951, one year after he had resigned from the Research Council. In October 1951 he sent the manuscript to *Chronica Botanica*, the publishing house of his friend Frans Verdoorn in Waltham (USA).

This version of *Geobiology*, is more complete than the 1944 version, although the 239 figures are lacking. However, with exception of the chapters on water, symbiosis and the (destructive) role of man on his environment, most of the remaining chapters have the character of a college manual. The text is largely descriptive. Moreover, the endless summing up of information in paragraphs sometimes seems more like an urge to be complete and not as a means to explain a process of a phenomenon. Baas Becking's editor Frans Verdoorn wrote:

> You may feel that you have a book which forms one, single, organic unit, which cannot be broken up properly in three parts, but this is not true. While all of your manuscript deals with "Geobiology", the components are of different types:
>
> 1) *There are chapters (as chapters 1-3) which read like Distinguished-University-Guest-Speaker-Lectures, brilliant, but sketchy, miscellaneous, and sometimes pleasantly and cleverly anecdotal, just as such lectures have to be as time does not permit to deal fully with the subject which is also not the purpose of such a series of lectures.*
> 2) *There are chapters (5-8), which read like regular University Lectures, fairly detailed, as a textbook.*
> 3) *There is one chapter (4: Water) which is a masterful memoir of the international monograph type.*
>
> In my opinion, if we throw these three types of chapters together in one large tome, the result will be an uneven, unwieldy book and I suggest that your material be somewhat revised for publication in three parts.

In this review of the *Geobiology* manuscript, Verdoorn ignored the novelty of Baas Becking's understanding of symbiosis in Chapter VII. Chapter VIII on *Man* is also more than a regular university lecture. In the 1953 edition of *Geobiology*, this chapter has been stripped of the emotional eruptions that set the tone of this chapter in 1944. It is a long discourse in which the concept of symbiosis on man's relationship with his environment is analysed in detail. It is a thorough biological foundation of the Gaia concept that Baas Becking's work had developed since his Utrecht inaugural lecture in 1927. In March 1954 Baas Becking wrote to Verdoorn that he, "while impressed with the shortcomings of his own works, prefers, nevertheless, to see it published as a whole." As we mentioned in the above, *Geobiology*, updated until 1953, was not published in part or as a whole.

My friend Marcel Donze, Professor Emeritus of Environmental Aspects of Civil Engineering (Technical University Delft), who prepared a digital version of the 1953 manuscript from my 830 scans, remarked in 2019:

> There is no doubt that Baas Becking was a many sided scientist. He may be ranked as a first class scientist, judged by his creative work in a number of specialisms. In addition, he had much wider interests, and speculated as well as formed opinions about many subjects, without thorough knowledge. In his 1953 manuscript he tried to synthesise his vast knowledge and experience, aspiring completeness. This aspiration is one of the causes of the differences in quality over the whole manuscript.

Baas Becking's documents in the archives of the Australian Academy of Science show that after the rejection of his manuscript he still made an attempt to publish a revised version of Chapter IV *Water* under the title *Water in Biological Processes* and later as *The Realm of Water.* This attempt also failed, probably because of his poor health. In the Australian archive there is a document with the title *A System of Symbiotic Relations*, a slightly updated version of Chapter VII on symbiosis in the 1953 manuscript of *Geobiology*. Unfortunately, this manuscript has not found a publisher either. Yet at the end of his life, Baas Becking published a paper *Geology and Microbiology* (Baas Becking, 1959) in which he outlined in 34 paragraphs the microbiological aspects of geology. It is a summary of many topics also covered in *Geobiology* and therefore a kind of key that gives access to the two unpublished versions of his intended handbook *Geobiology*. Baas Becking's conclusion recapitulated his achievement in geobiology since his inaugural address *On the Universality of Life* in 1927.

> In any work involving sediments, recent or ancient, in any study of aqueous or atmospheric environments, we now realise fully that we have to take vital phenomena into consideration. Just as organic biochemistry has given great impetus to bacteriology in the study of the internal milieu of the microbes, there is an inorganic biochemistry which has to describe the geochemical reactions taking place on this earth in relation to the activity of its microbes. I am convinced that such a biochemical approach will be profitable.

Comparison of three versions of Geobiology

In Table 1, the tables of content of the three versions of *Geobiology* are presented to illustrate the changes in the structure of the text and the additions over a period of twenty years. The early 1934 version of *Geobiology* was mainly focused

71 *Trouw* November 25, 1948.

Table 1	Comparison of tables of content for three versions of Geobiology.		
Chapter	**Geobiologie 1934 and Geobiology 2016**	**Geobiology 1944**	**Geobiology 1953**
			Preface and Introduction
I	Introduction	The Problem	The Earth
II	The Environment	The Earth	The Organisms
III	Environment Factors: Solar Radiation	The Milieu	Milieu
IV	Environmental Factors: Temperature	The Organisms	Water
V	Environmental Factors: The Chemical Environment	Influence of the Milieu upon the Organisms	The Influence of the Environment on the Organism
VI	Cycles	Influence of the Organisms upon the Milieu	The Influence of Organisms on the Environment
VII	Oligotrophic Water	Mutual Influence of the Organisms	Symbiosis
VIII	Eutrophic Fresh Water	Man and Terrestrial Milieu	Man
IX	Oceans	Description of Natural Milieu	Epilogue
X	Brine	Tables and Literature	Legends for Figures
XI	Appendix		
XII	References		
XIII	Index		

on the environment of the organisms. In the two later versions these descriptions were integrated in a more mature, logical structure that reflected Baas Becking's concept of geobiology, the interaction of organisms and milieu. So, Chapters III, IV and V in *Geobiologie* (1934) became part of Section 3 *Milieu* and Section 6 *Influence of the Milieu upon Organisms* in the 1944 version of *Geobiology*; Chapter VI *Cycles* became part of Section 7 *Mutual Influence of the Organisms*.

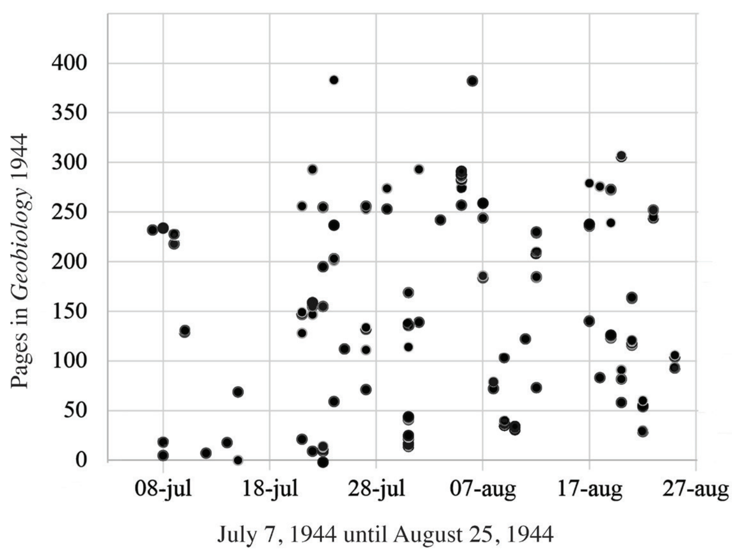
It is remarkable that Chapters VII, VIII, IX and IX on oligotrophic and eutrophic water types, oceans and brine in the 1934 version didn't get a distinct place in the 1944 manuscript of *Geobiology*. In the 1953 version however, they are described and discussed in detail in Chapter IV *Water*. In that manuscript there is even a kind of travelogue included, in which salt works, and 22 desert lakes, hot springs and volcanic waters are enumerated and described, based on Baas Becking's research in the later 1920s in California and in 1936 when he visited saltworks and saline waters in Portugal, India, Australia and the Dutch East Indies. In the 1944 version of *Geobiology* parts of his work and that of his students on halophytes are mostly only referred to, but hardly described.

In 2011 Aharon Oren reviewed Baas Becking's published papers on saline microorganisms in *The Halophilic World of Lourens Baas Becking*, which is besides that also a tribute to a remarkable scientist from a distinguished colleague (Oren, 2011).

Sections 7 *Mutual Influence of Organisms* and Section 8 *Man and Terrestrial Milieu* were additions to the text of *Geobiologie*. These Sections are introduced in the Section *Baas Becking's Scope of Geobiology.*

Baas Becking at Work on Geobiology

In the 1944 manuscript of *Geobiology* Baas Becking usually recorded the date of the day of his entries. In total there are 123 items with a date in *Geobiology*. Baas Becking spent 45 days in the Utrecht prison in that period he recorded on 33 days that he inserted one or more entries. Figure 1 shows that the insertions of text were not planned according to chapter, but were carried out apparently randomly over the 76 sections of the pre-defined table of contents.



Baas Becking activity in writing Geobiology *1944*

BAAS BECKING'S SCOPE OF *GEOBIOLOGY*

I know that I am talking about Gaia, the earth, as a living being. Maybe this is a form of pantheism and should, as such, be described. But was not everything marked down as heretical that ran counter to the make believe that left people to their greed and their breed?

Lourens Baas Becking (1942-1944), *The Kingdom of the World*

In this introduction, several central principles in Baas Becking's biological thinking in *Geobiology* are explained on the basis of his previously and later published and unpublished work. It becomes clear that there is an evident relationship between his personal perceptions of life and his scientific views on life and earth.

Ptolomeic or Terrestrial Outlook of Biology

One of Baas Becking's main inspirations for *Geobiology* was Lawrence Henderson's, *The Fitness of the Environment* (1913). Already in his lecture *On the Universality of Life* (1927), he referred with approval to Henderson, who drew according to Baas Becking, attention to the reciprocity between life and the earth: "Life has nested on the earth and is so close to her that the biosphere is in the opposite view of the other layers of the earth's crust". In that lecture he characterised the approach to biological research as 'Ptolomeic', a description that he also used in 1944 in the introduction of the Utrecht manuscript of *Geobiology* (Section 1.6). In his handwritten notes of his lecture course *General Physiology of the Cell* in Utrecht (1927-1928), he made another reference to 'Ptolomeic':

> Biology is still Ptolomeic, *i.e.* it is concerned with this thin varnish of living matter on our own Earth; all other biology is speculation. In this respect it is infinitely narrower than mathematics, which can abstract itself even from a cosmos, from physics which is also astrophysics, with chemistry which deals with compounds never seen in the earth, even narrower than geology in as far as it understands the mineralogy of the moon. It is however wider than both chemistry and physics because it has to study terrestrial conditions much more carefully.

In his inaugural lecture in Leiden, *Gaia or Life and Earth* in 1931, he further specified the 'Ptolomeic' approach of biology:

> Biology is bound to the earth in such a way that all reflections on cosmic life, panspermia and the like still belong to the realm of pure hypothesis. Biology is therefore, bound to the Earth, a geocentric science, and especially where it describes and does not experiment. This seems, at first glance, to be an inevitable limitation. However, it is my conviction that this restriction, like so many others in natural science, is based on human prejudice.

In his notes for one of the last lectures of his university course in Utrecht, May 1928, we find under the heading *Scope of Biology*, a further reflection on the essence of biology:

> The greatest limiting factor in the progress of this science of biology however, is man. Not in the trivial sense that man is only an imperfect tool, an unclean lens, but that every scientist is, consciously or subconsciously trying to arrive at an orderly cosmogony, which will satisfy himself. To satisfy himself means in the first place his feeling of safety and there is in biology not much to make him feel safe. This is, maybe, the reason why the concept of "miracle" has crept into biology by the way of the inapplicability of thermodynamics, that is maybe the reason an 'élan vital' or an "entelechy" have to assure us that all is well with the world.

'Elan Vital' and 'Entelechy'

In his published and unpublished work Baas Becking referred with approval to the Swiss physicist C.E. Guye, who classified 'life' as a not-material category with its own properties. In his *L'Evolution Physico-Chimique* (1922), Guye asked the question, how is it possible to understand life, when the world is ruled by the second law of thermodynamics, which points towards death and annihilation? By using a probability calculation, he assumed that even the production of a protein molecule by random assembly of atoms has such a high degree of improbability, that we can consider its formation practically impossible. The argument was used by him to reject the mechanistic interpretation of life:

> The biologist, at least until the end of the last century, dazzled by the success of physico-chemistry, quite often manifested a tendency to consider physiology as a physico-chemical outcome and was able as a philosopher, to believe that he is subject to determinism somehow unavoidable (Haeckel). […] We think on the contrary, although the current era is not particularly edifying in this respect, that the indisputable superiority of the human species compared with all species which are known to us, allows us to glimpse the possibility of a different evolution. If pity and justice apparently do not exist in the insect world, this does not prove

> that they should not exist in more evolved species and that this cannot even coincide, in a certain measure of course, with the general interest of a progressive evolution of humanity.[72]

Baas Becking apparently found his assurance in this concept, because in Section 4.1.2 of *Geobiology* he gave without restraint or relativity a description of Bergson's 'élan vital' as "an enormous urge which presses every living thing to procreate, to make more of its sameness." In Section 5.8.2, he expressed himself positive about Driesch's entelechy concept, which indicated a life force conceived of as *psychoid* or "mind-like", that is; non-spatial, intensive, and qualitative rather than spatial, extensive, and quantitative. In an unpublished lecture *Forgotten Biology* given in June 1951 in Sydney however, he expressed his ambivalence.[73] Although he realised the importance of the conclusions and predictions of his scientific ancestors, "on the whole these historical achievements seem to care little. It develops, in a way, haphazardly and the efforts frequently dichotomise. Certain of these bifurcations continue to grow, while others are repressed, or become abortive." In the lecture he mentioned "the antithesis between theorising and experimentation, between the inductive and the deductive mode of thinking."

> The "inductive school", a long time linked with vitalism, had most sympathy from the philosophers. It survives in the modern typology of Troll, in the Holism of Smuts, in Hans Driesch's "Organic Philosophy". Still there is more than there was dreamt of in their philosophy. It is true that an experiment is a question put to Nature, and the answer may be more or less oracular, dependent upon the sense we put into our experimentation. The inductive biologist, however, is prone to act as "magister" rather than as "minister", or better still "interrogator naturae". He soon tires of the wearisome examination and goes back to his desk to create more systems.
>
> The experimentalist at the other hand finds his support in the "purer" sciences and in pragmatic philosophy. He asks only what is the truth "today". He tries to translate his results into chemistry, physics and mathematics. My respected teacher, Jacques Loeb, saw a future for biology in which the certainty of the results would equal those in chemistry and physics. However, the principle of uncertainty has entered in both chemistry and physics and, as living beings represent statistical populations of a much lesser magnitude than those met with in the molecular, the atomic or the electronic state. The individual freedom of the variant always leaves its hallmark upon the results.

At the end he remarked: "I have never been able to decide between the respective merits of synthetic or analytical thinking, or between those of a mechanistic - or a vitalistic attitude towards biology. In this I have good company." Apparently however, the assumption or rejection of 'synthetic thinking' mattered much to him, as is evident in a contemptuous note in 1959 about John Burdon Sanderson Haldane's remark in *The Origins of Life* (1954) that although "the full area of ignorance is not mapped, [he] did not see any necessity to falter and invoke *'deus ex machina.'*" Baas Becking angrily remarked "This is a supreme conceit LBB." Furthermore he characterised the approach as "Quizz Kid" attitude: "clever and clever. Got all the answers, but science consists to ask questions of nature and if the questions are intelligent the answer will be intelligible. 'What question should we put'?"[74]

Dissipation and the Entropy Lowering Capacity of Living Systems

In Section 6.1.1 Baas Becking described "the entropy lowering capacity of living systems." It appeared to him that this capacity was "chiefly concerned with dissipation, rather than entropy." In his Robert Mayer centennial lecture in November 1942, he discussed the concept of dissipation as a kind of physical analogue of entropy, thus trying to find an analogue of entropy as a way to explain life's phenomena (Baas Becking, 1942a). In an unpublished manuscript written in 1945 or beginning 1946 he wrote:

> The restriction that Clausius gave (1867) to the law of the conservation of energy of Robert Mayer (1842), by the introduction of the entropy concept is analogous to the restriction given by the concept of dissipation to the law of conservation of matter, or Lavoisier's law. In analogy with Bolzmann we might state: While the amount of terrestrial matter is constant (with the restriction of the introduction of cosmic matter and of atomic disintegration) dissipation is on the increase. But while, in irreversible reactions, the entropy increases, and overall-entropy is increasing, living beings are able to cause a decrease in dissipation. Living beings may, selectively, change outer environment into inner environment.[75]

In 1948, in his curriculum vitae for the South Pacific Commission he characterised his "derivation of the concept of dissipation", as one of the eight chief results of his professional career.

In his idea, the fundamental difference of material dissipation with entropy was, that the "human intellect as well as the living condition" were able to decrease the dissipation. In Section 6.1.1 of *Geobiology* he summarised his ideas and referred to the physicist Burgers, who disagreed with Baas Becking and maintained that the second law of thermodynamics also applied to the living world (Burgers, 1943). In his essay *On the Determined and Undetermined in Biology*, which Baas Becking submitted for publication in February 1944, two months before his failed attempt to escape to England, he maintained his stance and expressed his "feeling", "that in living nature, there stands established a principle, which may be called the 'unique event', and that this event implies the presence, in this scheme of things, of a directive force" (Baas Becking, 1946b). Here the unique event was "a steep, local decrease of entropy, statistically smoothed out by a general decrease of the free energy level." He deduced his "feeling" from Kant's *Kritik der reinen Vernunft*, in which a distinction is made between nature, which is only a complex

72 Charles-Eugene Guye (1886-1942), Swiss physicist. Baas Becking referred to Charles-Eugene Guye (1922) *L'Evolution Physico-Chimique* (translated in 1925 by J.R. Clarke as *Physico-Chemical Evolution*) and Charles-Eugene Guye (1937).

73 Forgotten Biology, lecture given by L.G.M. Baas Becking June 6, 1951, for C.S.I.R.O. Homebush (Sydney). Typescript with corrections by AAS Basser collection 043 nr. 161.

74 Handwritten remarks for *Lecture On the Origin of Life*, December 9, 1959, Masson Theatre, University of Melbourne. 'On the Origin of Life'. AAS Basser collection 043 nr. 165.

75 Manuscript Baas Becking (1945-1946), "Seawater as a chemical milieu". The manuscript was dedicated to Jacoba Ruinen. Manuscript in private collection.

of phenomena that conform to laws and at the same time laws that are not primarily inherent in nature, but are prescribed by our reason. Baas Becking came to the conclusion that:

> The individual has the attribute of free will, the attribute Divine, the character of the continuous and of the infinite; the statistical ensemble is pre-destined, it is governed by chance (= law), it is based upon discontinuity and upon limitation.

Baas Becking typified himself in 1946 as, "I, who can connect no image and no gesture to God."[76] To characterise Baas Becking's term 'divinity', it is therefore good to realise, that in his unpublished manuscripts he made a distinction between religiosity and commitment to a church or faith. Among the first was his deeply felt sense of God, while the human centred 'ecclesiastic' systems were part of the second category. The last was represented by the clergy, which he usually described disparagingly as is evident in Chapter VIII of *Geobiology*. His religious view of God, the world and humanity were described in *The Kingdom of this World* (Baas Becking, 1942-1943):

> Only in the harmony of a living being with its environment we shall find our happiness. […] Happiness is however, chiefly in creation, in crystallising thought, in graphic representation, in music, in science. And happiness again, lies in the contemplation of what is beautiful, and all this happiness is not pagan felicity, it is pervaded by charity, it is pervaded by God, and one of God's greatest manifestations is this earth, and he made us stewards over this earth, and the happiness should come from this earth, because God gave it to us as a dwelling-place. This is the Kingdom of this World.

Everything is Everywhere, *but* the Milieu Selects

In his 1948 curriculum vitae Baas Becking mentioned "Proof of the omnipresence of air borne organisms (selective milieu)", as one of the chief results of his scientific work.[77] This is a very brief and more limited description of his famous 'ubiquity law' as it was published in 1934 in *Geobiologie* and in Section 1.6.3 of the present *Geobiology* transcription. During all his professional career Baas Becking used the word 'law' for M.W. Beijerinck's "inspiration from the belief that most microbes are omnipresent" (Baas Becking, 1959). From the contemporary perspective of the biogeographer of microorganisms however, it is better to speak about 'hypothesis' and to omit the word 'dogma' that is used by some authors.[78] Already in 1927 in his inaugural lecture, *On the Universality of Life*, Baas Becking concluded: "Life is eternal, there is potential everywhere, the milieu selects, determines the form. The earth's general standard is only a particular case." In his inaugural oration in Leiden in 1931, *Gaia or Life and Earth*, he formulated:

> The cosmopolitan occurrence of lower organisms, which gives us the basis for the study of external conditions, is curious enough to be elevated in ecology to a rule, to a law, to "the law of Beijerinck". A law that says "everything is everywhere". Everything is everywhere, and the milieu selects. The more extreme the milieu, the sharper the selection.

Baas Becking used 'Milieu' instead of 'Environment' in his English editions of 1944 and 1953, therefore *Everything is Everywhere,* but *the Milieu Selects*, is the version of the law that is authorised by Baas Becking. In Section 1.5 of *Geobiology* he gave a well-considered justification for his choice.[79] In the 1953 typescript of *Geobiology* he specified the 'ubiquity law' in the introduction of a paragraph of 12 pages, *The Distribution of Life on this Planet*:

> This holds both in nature and in the laboratory. The better defined the question, the sharper the answer. A very specific milieu, an extreme milieu (whether extreme in temperature, acidity or salt content) will sharply define a group of organisms occurring therein; whether bacteria, bluegreen algae, amoebae, flagellates or ciliates. But field ecology alone will never be able to give a complete answer as to the possible resonance of living systems and a given milieu; this answer is the prerogative of the laboratory.

To this day Baas Becking's ubiquity law is cited and critically discussed in microbiological publications. Therefore, after almost 90 years the ubiquity statement still offers inspiration for the research of biogeography of microorganisms and contributed to our understanding of microbial evolution.[80] Unfortunately Baas Becking's unpublished versions of *Geobiology* were not available for the research of the past two decades on the origin of the hypothesis and its philosophical background. So, his concept of 'Milieu' was not involved in the discussion of his ubiquity law.[81] Baas Becking's perception of the ubiquity hypothesis was therefore not studied. In the manuscripts of *Geobiology* he tried to understand the underlying mechanisms for the patterns of diversity and distribution of microorganisms and which determining factors are involved in the spatial and temporal distribution. My friend Professor Marcel Donze rated Baas Becking's ubiquity statement in 2019 after studying the 1953 manuscript of *Geobiology*:

> Everything is everywhere, which is not true, is an emotional exaggeration and an expression of amazement that by inoculating a sterile and selective growth medium usually the same kind of microbe will show up, independent of the place on earth and the microenvironment where the inoculum was obtained. The environment selects statement, is implicit in the previous statement, as far as enrichment cultures are concerned. It is also largely consistent with the mass occurrence of microbes as found in the field. But this is a much more difficult field: experimentally difficult, since proof, as compared with illustration in single cases, is much harder to obtain, among others since in the field many more variables happen to be present. It is to be expected that the primary influence of these is to exclude species that would be expected according to the laboratory analogue, a secondary influence to allow mass growth of another, or more species. The general conclusion is that the combination of dispersion and

76 Quote from De Gaay Fortman (1946).
77 AAS Basser collection 043 nr. 161, typescript.
78 See Fontaneto, D. (ed.) (2011); Wit and Bouvier (2006).
79 See also Wood and Baas Becking (1937), p. 336-338 in which he made a note on convergence and identity in relation to environment.
80 See Lachance (2004); Fenchel and Finlay (2003, 2004a, 2004b).
81 For a discussion of the roots of the 'ubiquity law' see O'Malley (2007, 2008) and Williams (2011).

survival under suboptimal to adverse conditions for growth combine such as to allow the presence of viable individuals under most circumstances on earth.

His assessment of the hypothesis corresponds with the conclusion of the symposium on *The Importance of Being Small: does Size Matter in Biogeography* that was held in Leiden in August 2009 (Fontaneto, 2011):

> The Everything is Everywhere hypothesis focuses on one single explanatory factor, dividing organisms into two main groups, larger organisms with biogeography and smaller ones without biogeography. Given the complexity of the spatial patterns in microorganisms, it seems that their biogeography is more likely to depend on a complex set of interacting phenomena, in which size is of course important, but it is not the only driver. The differences between micro- and macro-organisms can thus be included in a gradient, disregarding the hypothesised abrupt threshold assumed by the Everything is Everywhere hypothesis.

Life and Death

Section 4.9.8, *Death*, in *Geobiology* (1944) was concluded by Baas Becking with the observation that for "the further analysis of death and the longevity of organisms the special literature should be consulted." This he actually did in an unpublished lecture *The Nature of Death* for the Sydney University Biological Society in July 1953.[82] His lecture is interesting not only because he disconnects animate and inanimate from the individual human experience, but also because he presents life as a continuous process. It clarifies his view on geobiological processes in which life and earth are each other's countermoulds.

> The continuity of life is maintained, in the majority of organisms, by its nuclear structures which continuously rejuvenated by the sexual process, form a quasi-eternal track, the germ-track or "Keimbahn". In this immortality the importance of the individual is secondary; life is chiefly concerned with the maintenance of life as such.
>
> Life is an improbable event. As Robert Bridges says; "it holds balance on a razor's edge, that may not e'en be blunted, lest we sicken and die." Tight rope walking, and bicycle riding do not represent systems in equilibrium. These actions might be described as "continuous attempts to avert continuous falls". […] The self perpetuating pattern of life, with its combined free will and predestined trend, is something unique, it is not found elsewhere.
>
> Life itself is a megachronic phenomenon, like the earth, the solar system and the universe. Life has fought on all planes, almost down to the leptochronic (the divisions given are more or less arbitrary). Death is nothing in itself. It is a term, describing the transition from the highest organisation form of matter to the molecular. Life is an intricate, developing pattern of molecules and ions, death is shapeless. […] Thus far life has been persistent on this planet. Let us hope that our species will not be a great contributary cause to the death of the thin and vulnerable green living veil of this earth; to sustain life is more precious than the cheap act of making life cease.

Ammonia Chemistry

In his early work Baas Becking discussed non-terrestrial biology and the "ammonia chemistry" of Edward Curtis Franklin of Stanford University. Baas Becking called Franklin "a brilliant chemist, whose lectures I followed at Stanford University."[83] Evidently, liquid ammonia as an alternative substance of water, carrying colloidal and living substances in solution, was a topic that fascinated him during his professional life. In *Geobiology* he mentioned and discussed it in several paragraphs (Section 2.5.1 and 2.5.2). The ammonia chemistry was already discussed in his Inaugural Address at Utrecht University in 1927:

> And it is the great merit of a man, with whom I had the privilege of dealing almost daily during the last six years, Edward Curtis Franklin of Stanford University, that he has projected a chemistry and worked out with tremendous experimental power; a chemistry wherein the liquid ammonia takes the place of the water in the general chemistry. Franklin has succeeded in creating an entire "ammono" system of acids and salts and bases. He has also been able to find the ammonia analogues of several "aqua-organic" substances. Ammonia is in many ways a liquid analogous to water, so similar to water that even Henderson gets scared of it. None other than Sir William Maddock Baylis admits the possibility of an "ammonia life".[84] Henderson rejects the possibility of ammonia as a life carrier and grounds his objections to the fact that ammonia has neither the anomaly expansion of water, and still stands on a sufficiently low level of free energy, the formation heat of water is ten times far greater than that of ammonia. Henderson calls this last "… an insurmountable obstacle to the substitution of ammonia for water in biological processes …"[85]

In *Geobiology* (1953) he remarked:

> Liquid ammonia shows many special, extreme chemical and physical properties, only shared with water. It might create a suitable vital environment. There is no reason whatsoever why we could not experiment with ammonia systems at the temperatures of the corresponding state of the water system (-65 °C). In the atmospheres of the outer planets, we would meet a true "Franklinian" chemistry. Whether "Franklinonts" exists on these planets is a question of conjecture; but if life is an inevitable state of matter they should exist.

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82 AAS Basser collection 043 nr. 163, typescript, *The Nature of Death*, lecture given for the Sydney University Biological Society July 14, 1953. See Baas Becking (1953b).

83 Baas Becking (1962). The reference is to Edward Curtis Franklin (1862-1937) was a Professor of Chemistry at Stanford University, author of *The Nitrogen System of Compounds, a Monograph* that was published by Franklin in 1935.

84 Sir William Maddock Bayliss (1860-1924), English Physiologist. The reference is to William Maddock Bayliss's *Principles of General Physiology*, here quoted from the third revised edition (1920) p. 228:

> In a world in which liquid ammonia took the place of water, another kind of complex organisation might have been developed; although, it must be admitted, it seems impossible that the complexities and endowments of the "organisms" formed could ever reach the perfection of those which we know under the present conditions.

85 Baas Becking referred to Chapter VII of Laurence Henderson's *The Fitness of the Environment* (1913, p. 263-265), in which an extensive note about the studies on the properties of liquid ammonia as a solvent by Edward Curtis Franklin and his students in the first two decades of the 20th century.

However, his plea for ammonium chemistry was unsuccessful. In December 1959 in Baas Becking's last public address during the *Symposium to Mark the Centenary of Darwin's "Origin of Species"* in Melbourne, he again brought Franklin's ammonium chemistry to the attention of his audience.[86] There he referred to his own experiment with ammonia in 1934:

> Now for the first time I will confess a series of crazy experiments I performed with the help of a well-known physicist, more than twenty years ago. We prepared bacteriological culture media carefully translating the hydro-compounds into the ammono-compounds. The liquid phase was ammonia and the temperature was – [minus] 50 °C. We infected with desert dust, to have something alive and still uncontaminated. The infected cultures turned red. But the experiments broke down when we wanted to examine the cultures under the microscope. This we could perform only at room temperature and by heating to room temperature we generated about 90 atmospheres pressure. We examined the cultures through a hole drilled in a rifle barrel. Most of the cultures exploded and one went clear through a heavy door. By heating to this room temperature, we probably had boiled the organisms, if present. What we saw we photographed, but we put no trust in it and we never dared to peep about it. The war came and we drifted apart. The experiment was never repeated.

In his lecture he summarised his earlier plea for experiments with ammonia:

> There are at least three reasons why these compounds should deserve our particular attention. In the first place it is almost certain that they were present in the atmosphere in Proterozoic days. Further they are playing a great role in the synthesis of organic compounds while, and this may be the most important reason, they are constituents of the atmospheres of the large planets. E.C. Franklin has devoted a lifetime to the study of the ammonia system of compounds and has shown that liquid ammonia not only has much in common with water, but that at -65 °C a whole ammonia system of compounds exists, analogous to the water system. Our Ptolomeic system made place for the Copernican, physics and chemistry are consulting the stars and have become astrophysics and astrochemistry. If life is an inevitable state of matter it would be not too far-fetched to assume ammonia systems to be possible carriers of life, a statement to which Haldane concurs. Urey however claims that the water system is the only one, because we know enough about such systems as the ammonia system.
>
> In the face of the extreme importance of the matter […] and in order to get rid of the "water bogey" which is bothering us now and which may be the cause of the appointment of an Astrobotanist in the U.S.S.R and from which we hear that he is experimenting with tomatoes…, certainly not "ammonobionts"… In the last 25 years cryogenic technique has doubtlessly advanced and instead of using the ammonia analogues of "water" organic compounds try to grow autotrophs, with carbon dioxide and hydrogen in liquid ammonia.

In his handwritten notes for the lecture in December 1959 Baas Becking complained like a misunderstood scholar about Urey's statement, "that the ammonia, methane and H_2S systems have been sufficiently studied and let it go at that […] and he continues 'life is bound to water'. No highly complex system of chemical reactions similar to that which we call 'living would be possible in such media'. How does he know?" He referred to Harold Clayton Urey (1893-1981), American physical chemist, who was awarded the Nobel Prize in Chemistry in 1934 for "his discovery of heavy hydrogen."

Symbiosis and "Nothing in the World is Single"

In Section 7, *Mutual Influence of Organisms* in the 1944 and *Symbiosis* in the 1953 version of *Geobiology*, Baas Becking's 'universal concept of symbiosis' – as Quispel (1998) called it - was included. It was based on the idea of "mutual dependence of vital units (cells, tissues, organs, organisms) either of a parasitic, mutualistic or commensalistic character." In 1948 Baas Becking considered that "Extension of our modern concept of symbiosis" had been another chief result of his career in biology. Quispel (1998) remarked:

> It might be objected that such a broad definition of symbiosis takes much away from the original definition However, the present insight in the role of biochemically related signals in differentiation and morphogenesis, as well as in plant (or animal)-microbe interactions, shows that it can now be considered as a far seeing view. He did, however, ask me to include a short description of his concept of endosymbiosis in the introduction to my PhD thesis of 1943, which alas has remained its only published form.[87]

The concept included not only interactions between organisms, but also processes within cells and tissues. The 'histosymbiose' for example comprised the collaboration of the different tissues, which together constitute the living organism. Microorganisms and multicellular organisms were involved, but also higher plants and animals. The concept further included man. Baas Becking also widened the original concept symbiosis of De Bary of a mutualistic relation between two different organisms by symbiotic relations occurring in a single organism or between organisms of the same species. These were named auto- or homoiosymbiotic relations by him in contrast with the heterosymbiotic relations of De Bary.

In the transcript of *Geobiology* the broad concept of symbiosis is introduced in Section 1.6.3. with a quote from Percy Bysshe Sheley's *Love Philosophy* (1819): "Nothing in the world is single." From his short explanation and the content of Section 7, it is evident that Baas Becking considered the statement as a biological law, just like 'Everything is Everywhere *but* the Milieu Selects'. Derx (1947) summarised Baas Becking's central idea of the symbiosis concept:

> It should indeed be realised that it might well be, that strict autotrophy exists only as a mental extrapolation. Though green plants are generally supposed to be "self supporting" even these are frequently found to be dependent in one way or another on the co-operation of microbes. Living matter is symbiotic in essence; mutual dependences in every degree, in every imaginable form

86 Typescript of Draft AAS Basser collection 043 nr. 165-3. *Lecture December 9, 1959, Masson Theatre, University of Melbourne.* Baas Becking's lecture *On the Origin of Life*, was published in Leeper (1962, p. 33-40).

87 Quispel (1943, 1946), p 416-419.

are to be found everywhere. Consequently, symbiosis in some form must necessarily pervade the numberless manifestations of that single autonomous phenomenon: Life.

Man was an important participant in his symbiosis concept, as he in an unpublished lecture *Our Relations to the Earth* in Sydney in the early 1950s expressed:

> In this technological age (and truly the hand has matured before the brain) we are apt to forget that we are also vertebrate animals, living in symbiosis with a great number of other organisms. In the web of life, we only represent a single knot, we are connected with a multitude of other living beings. These connections range from plain killing, via parasitism to domestication and exploitation, both inter- and intra-specific, further antagonism (most of the present human relations) to a true mutualism, which is the rarest form of' symbiosis. The term "metabiosis" designates a succession of organisms in which a pioneer prepares the environment for a successor. History, in a way is a description of intra-specific metabiosis. [88]

The framework of symbiosis in the 1944 version of *Geobiology* Baas Becking distinguished 33 forms of symbiosis (Table 7.2a), which he illustrated by examples (Table 7.2b). 'Slaves, fungus, garden seed dispersal of ants' is a symbiosis example of helotism, exploitation of individuals in a community. In the 1953 version 89 forms of symbiosis were classified, an example of his urge to be complete. Therefore, a description as 'divorce, rivalry of the sexes', was entered as an example of antagonism within the group homoiosymbiosis, specified as gamosymbiosis. 'Euneuchs, harems, primitive marriage, civil code' and 'pimps, prostitutes, certain forms of marriage' were other forms of gamosymbiosis, and examples of 'helotism' and 'parasitism'. Baas Becking remarked:

> If man were exclusively considered in this scheme, a great many poems, novels, and plays could be classified with ease. When the poet says: "Du bist wie eine Blume", we classify this utterance as "hetero-gamo-mimesis."

Baas Becking's concept of symbiosis was not only summarised by Quispel (1943, 1946) in the introduction of his PhD thesis, but also discussed in a communication to the Royal Netherlands Academy of Arts and Sciences in Amsterdam by his friend and colleague Henry Derx in 1947. However, they published their papers in journals outside the mainstream of scientific information exchange at the time. Therefore, Baas Becking's symbiosis concept unfortunately remained unknown and didn't play a role in Sapp's *History of Symbiosis* (Sapp, 1994) or in Oliver and Russell (2016) *Introduction to Symbiosis*.

Man and Terrestrial Milieu

The two manuscripts of *Geobiology* include a Section 8 on *Man*, a topic strongly related to his symbiosis concept. Like the Section 7 on symbiosis, it was an addition to the original text of *Geobiologie* (1934). There is a major contrast between the two unpublished manuscripts. The 1944 version is mostly based on the most gripping document in Baas Becking's scientific legacy, *The Kingdom of this World*, which he began on December 13, 1942, one week after his beloved sister-in-law Elize Haverman-Pinke died of breast cancer.[89] Baas Becking had cared for her and her sons in Scheveningen in the last months before her death. Writing was for him a form of grief processing. *The Kingdom of this World* gives us an insight into his anguish, indignation and sadness marked by the war and personal suffering. Only seven chapters out of the twenty that were planned, were finished in the handwritten 86 pages of *The Kingdom of this World*. They supply information for the paragraphs in Section 8 that were left blank in the 1944 version of *Geobiology*.

> It is useful to analyse our relation to the earth. It may cover us with shame. It may (I hope) make us realise that we have committed a grave, communal sin to God, far greater than any trespass of any commandment given in our scriptures; it may make us realise that every one of us, whether priest, soldier, farmer, engineer or scientist, have contributed their share to make the earth less worthwhile, less inhabitable. Like town rabble in an unprotected orchard, like locusts in a corn field, we have brutalised and mauled our own mother. Our only mother, for if we finally choke in our own excretion products, there is no other planet for us to devastate. I want to prove:
>
> 1) That this devastation is imminent,
>
> 2) That it will become irreversible within a few generations,
>
> 3) That, unless "economic theory" is radically changed, the end is certain,
>
> 4) That practical measures may be developed to make a new earth and, because of this new earth, a new race of Man.
>
> I intend however to use only the most trivial sources, the most everyday examples, the accepted scientific truths. As a biologist I have a trained eye, as a man I had a long and varied life. I do not want to drag myself through libraries any more, for there I only find Man, looking in adoration at its own image, or damming this world with (and because of) this damnable Man and referring the latter to the hereafter. Surely, the dead cannot pay their debts. I prefer to tell my tale without help from the living or from the dead, aren't they all culprits? They all stand accused. I shall try to be the council for the Earth. She is mute, she is old, she is long suffering and she is about to die. Cease your money making, you idiots, and listen. Your mother is dying!

The 1953 version of Chapter VIII *Man* lacks the emotional and very personal approach of the 1944 version. In nine sections and 52 paragraphs Baas Becking gave a much more complete and balanced biological assessment of the relation between the living organisms and the earth:

> Civilisation, as the exoteric aspect of culture, while changing its structure continuously has entered, only a few generations ago, a new and unusual developmental phase, this phase of increased growth and differentiation was preceded by a global exploration. In the last 150 years the impact of man upon the earth has increased to an unprecedented value; by increase in numbers but much more so by the increase in wants. This increased impact has been harmful to the earth's surface.

88 AAS Basser collection 043 nr. 112-10 typescript several copies of the manuscript also a handwritten version.

89 Manuscript *Kingdom of this World*, L.G.M. Baas Becking, Universiteitsbibliotheek Leiden BPL 3233.
Baas Becking wrote *The Kingdom of this World*, with the intention to "make the relationship of man to the earth part of a treatise". This idea he formed during the six months in the "cell baracks of the Scheveningen prison" of the German *Sicherheitspolizei* after an earlier attempt to escape to England in October 1940.

Potentially, the influence of man is proportional both to numbers and to his wants, and this influence might be counteracted by another product, a product of numbers and individual creative (or restorative) powers. As the wants, however, are common to all variants and the creative powers given to a few only, dissipation of the earth's surface, dissipation of goods and of energy is going on unabated, in spite of the repeated warnings of the few.

The attitude of man towards the earth is still, on the whole, that of a parasite. For a parasite, however, the life of the host is of prime importance and even if our attitude should remain unchanged the human race could persist on a rationally exploited earth. It is the task of the sociologist to find a reason for human attitudes, but the relation of man at the earth concerns biologists as well. The biological point of view may be a narrow one and much that has been said in this chapter should probably be ascribed to the specialised attitude of a biologist. If this attitude leads us astray, the question might arise, astray from where? For there are no long term plans, no long term directives for mankind. To be optimistic about the future of humanity (as a function of the future of the earth) may be a comfort to those who refuse to appraise, objectively, the present situation.

It is painful to note, that more than 75 years after Baas Becking formulated his analysis and conclusions about the harmful role of humans on their environment, they are still of topical value.

ANNOTATIONS

Geobiology certainly does not fit anymore in the current mainstream of geochemistry and geobiology research. Therefore, the text of the unfinished manuscript of *Geobiology* needs an elucidation to be able to appreciate the components in their context. This is all the more important because it has been more than 75 years since the manuscript was written. Much of the work discussed in the document is nowadays outdated, difficult to find and unknown to the contemporary reader. The published work from his research group in the Leiden Botanical Laboratory the 1930s was largely "buried in the Recueil or in the Academy Proceedings", as Baas Becking characterised the relatively obscure journals that published quickly and without peer review.[90]

A significant amount of Baas Becking's work has remained unpublished. However, many unpublished documents were available for me as editor in the form of digital copies from archives in the Netherlands and Australia. Moreover, part of Baas Becking's scientific work is also available on the internet. To clarify the text, various parts of the manuscript have been supplemented with information from Baas Becking's own work, published as well as unpublished. The annotations identify most of the incomplete or incorrect references in the manuscript. The notes present biographical information about the authors of these sources and supply descriptions on what they deal with. The explanations and annotations attempt to place the work of Baas Becking in a time perspective, which is why parts of the typescript of the 1953 version of *Geobiologie*, have also been quoted. In addition, in some places reference has been made to more recent research.

The transcript of *Geobiology* contains editorial explanations and additions, these are placed in square brackets. In case Baas Becking omitted to give a reference without year of appearance this was silently entered in the text. In addition, many wrongly written names of authors or persons have been tacitly corrected. On several places there are notes, usually references to literature written in ink. These were probably entered in the ledger before Baas Becking was in the Utrecht prison, because there he only had a pencil for writing the entries. The parts in ink are in text boxes in the transcript.

Most of Baas Becking's documents are written in English. Several early publications and his inaugural orations in Utrecht (1927) and Leiden (1931) are in Dutch. In case these sources are cited, they have been tacitly translated into English.

Description of the Manuscript of Geobiology

The manuscript of *Geobiology* is a ledger with a hard cardboard cover that is covered with black paper. The spine of the book and the corners of the cover are overlaid with gray linen. The cover has a hole on the front through which the damaged cardboard is visible. The ledger is from the company of Planeta D.B. and M.R. 5048 B. Size of the ledger is 16.5 × 21.5 cm, 383 pages numbered by hand in ink; 388 pages in

90 The reference is to *The Recueil des Travaux Botaniques Néerlandais* and *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen te Amsterdam*. During the German occupation of The Netherlands in WWII the prefix 'Koninklijk' [Royal] was forbidden.

total, cover included. There is a sticker on the inside with the name of the bookseller: N.V. A. Dorsman's boekhandel and Drukkerij, Voorstraat 51-53, Noordwijk-Binnen.

Triangular Plots, Ternary Plots, Gibb's or Stokes Triangles

In *Geobiology* (1934), Chapters VIII, IX and X, Baas Becking used ternary plots to display the composition of waters. The plots graphically depict the ratios of three components as positions in an equilateral triangle. In a ternary plot, the values of the three variables *a*, *b*, and *c* must sum to some constant, usually 1 or 100 %. In the 1953 version of *Geobiology* he remarked that "a complex of three variables may be represented by this method showing a considerable advantage of the, more usual, plane representation of a space model. It widens our scope in many respects and allows of a welcome extension of the visual methods, so dear to the biologist."

The triangular plots were frequently used by Baas Becking in the 1944 manuscript. In Section 3 of *Geobiology* he used the ternary plot to depict the composition of the soil and of brines. In Section 5 the plots were used to analyse seawater, natural and saline waters, by depicting the ratios of the cations and anions of NaCl, $CaHCO_3^-$ and $MgSO_4$ in the triangle. In that section, he also visualised the differences between blood and seawater. In several plots he enlarged the triangle by adding to each of the three sides of the triangle another one with SiO_3 in the opposite angle (Fig. 5.14). So, he constructed a 2 D version of a 3 D tetrahedron or triangular pyramid, to depict the composition of waters for four components. The same he did to illustrate the oxidation and reduction of iron compounds in the lithosphere and in seawater by adding sulphur to the triangular plot, thereby also visualising the relative position of sulphur compounds (Fig. 3.13).

In Sections 3 and 6 most of the triangular plots refer to the metabolic processes in which oxygen and hydrogen are related with carbon, nitrogen or sulphur. In this way he tried to show the chemical processes such as oxidation and reduction, hydrogenation, dehydrogenation, carbonisation and caramelisation. He also tried to relate the reduction stage of carbon compounds with heat combustion. Plates 3.2 and 3.3 in the 1944 manuscript were probably preliminary studies of his article *On the Graphical Representation of Chemical Processes*, which was published in 1947 (Baas Becking, 1947b).

Several of the drawings of plots in the manuscript of *Geobiology* are difficult to interpret, because they contain too much information, but too little explanation of the graphically displayed data. However, it is usually evident what Baas Becking proposed to show with his plots, although the graphical exercises seem like a quest to illustrate chemical processes in a novel way. The ternary plots give an idea of his fascination for this form of visualising chemical processes and compositions of substrates and water types. In the oppressive reality of his captivity, that search also must have meant a distraction to him. We therefore chose to leave these plots intact and display these in the transcription like the other figures as in the original manuscript.

ACKNOWLEDGEMENTS

After I graduated as a plant physiologist in Leiden in 1974, I decided never to practice this profession. I became a fisheries biologist and obtained my PhD as an historian. Peter Westbroek and Don Canfield brought me back to plant physiology, an enriching experience after nearly 50 years of absence. The annotated transcription of *Geobiology* is thus "A Work of Redemption", not in a moral sense like Lawrence Sterne's fictional travelogue *Sentimental Journey* (1768), but in a secular sense: an acknowledgement of my youthful prejudices. It is a belated tribute to Baas Becking and my teacher Anton Quispel. I am very grateful to my friend and former supervisor Marcel Donze for his support and his selfless help to make the 830 pages of Baas Beckings *Geobiology* 1953 typescript accessible for me. Many thanks to the staff of the Australian Academy of Science in Canberra who scanned a large part of the Baas Becking archive in the Adolph Basser Library Manuscript Collection: Clare McLellan, Robyn Diamond, Ellen Rykers, Melanie Bagg, Felicity McCook. I thank the family of Lourens Baas Becking in Australia and The Netherlands for their interest in my research and the information that I received from them: Francesca Baas Becking, Ingrid Baas Becking, Steven Teding van Berkhout, Nils de Sitter, Aernout de Sitter. Willem Otterspeer made the sources for his book about Leiden University during the Second World War *Het Horzelnest Nest* (2019), available to me. The members of the Baas Becking Society were a continuous support for me. I would like to thank Juan Diego Rodriguez Blanco for his work redrawing several figures, as well as Marie-Aude Hulshoff and Robert Raiswell for their excellent and adequate editorial assistance, which improved the readability of Baas Becking's manuscript of *Geobiology*.

From the beginning, Annemarie van Santen was involved in my research. I am intensely happy that we were able to reach the end of this undertaking together.

This annotated *Geobiology* transcription is dedicated to my two granddaughters Sofie and Julia Raat, for whom I desire a better world than the one described by Baas Becking.

Alexander J.P. Raat

GEOBIOLOGY

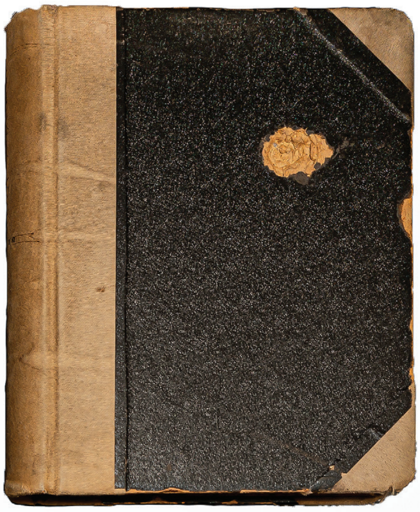
ABSTRACT

Lourens Baas Becking (1895-1963) was a Dutch plant physiologist, trained in the Botanical Laboratory of Utrecht University. After graduating in 1919, he worked in America at Stanford University, where he obtained his Doctor's degree in 1921. From 1928, he was Herzstein Professor of Biology and Director of the Jacques Loeb Physiological Laboratory at the Hopkins Marine Station in Palo Alto. In 1931, he became Professor of General Botany at the University of Leiden. There, he and his staff and students continued to work on the research of microorganisms under extreme saline conditions. In 1939, he was appointed Director of the institutes of the Botanic Garden at Buitenzorg (Bogor) in the Dutch East Indies (Indonesia). In May 1940, when the war broke out, he was in Leiden to retire from his professorship. The war prevented his return to his family and the institutes in the East Indies. Baas Becking made several failed attempts to escape to England. These resulted in imprisonments by the German occupying authorities in Scheveningen (1940-1941) and in Utrecht and the German *Zuchthaus* in Siegburg (1944-1945). An ordeal that he barely survived due to the inhuman situation in the penitentiary and typhus.

In July and August 1944, as a prisoner of the German *Kriegsmarine* in Utrecht, he wrote in seven weeks a manuscript of *Geobiology*, an essay on the relationship between living organisms and the earth. It was an update of his earlier ideas. Baas Becking had been inspired by Lawrence Henderson's *The Fitness of the Environment* (1913), Victor Moritz Goldschmidt's *Der Stoffwechsel der Erde* (1922) and *Grundlagen der quantitativen Geochemie* (1933), Alfred J. Lotka's *Elements of Physical Biology* (1924) and Vladimir Vernadsky's *La Géochimie* (1924). They were with Frank W. Clarke's *The Data of Geochemistry* (1916), sources for his perception of *The Universality of Life* in 1927, which integrated Vernadsky's concepts of biosphere and geosphere. Long before James Lovelock and Lynn Margulis defined the Gaia hypothesis in the early 1970s, Baas Becking discussed *Gaia or Life and Earth* in his inaugural address in 1931. In this tract he also succinctly summarised the ubiquity hypothesis, borrowed from the work of Martinus Beijerinck, as "*Everything is everywhere,* but *the Milieu selects.*" The biological "law" was further elaborated in *Geobiologie of inleiding tot de milieukunde* (1934, English version 2016, *Baas Becking's Geobiology*).

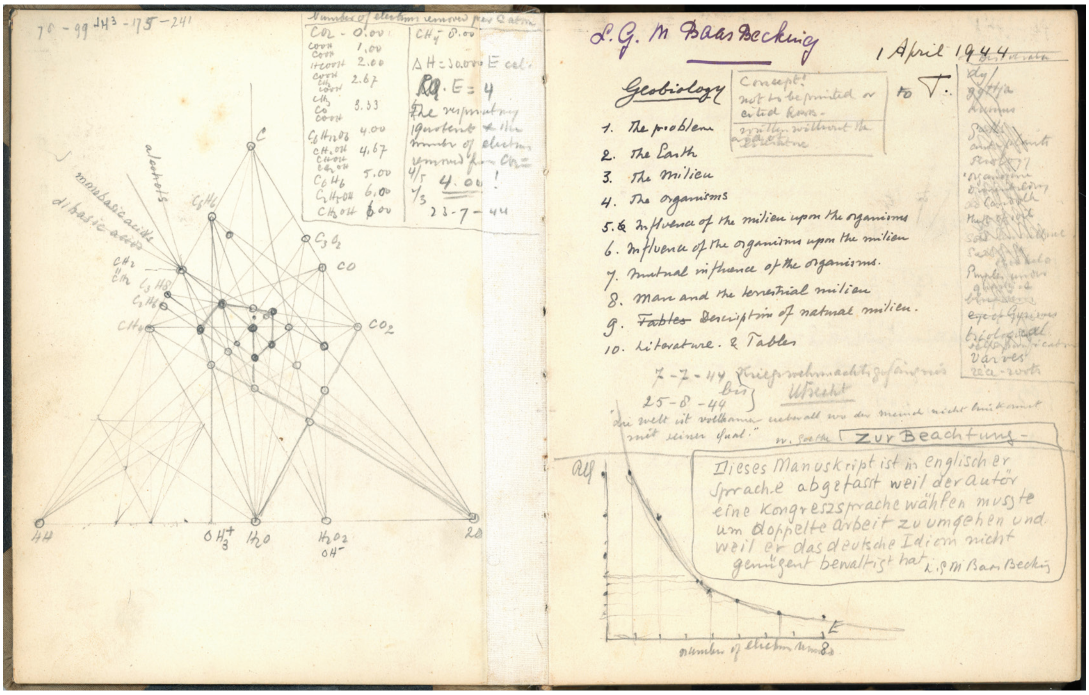
In the Utrecht prison Baas Becking wrote his scientific testament. In the ten years since the publication of *Geobiologie*, he "wished to do justice to the work that was performed in Leiden by so many workers", in an English textbook. With a limited access to scientific literature, he wrote the manuscript *Geobiology* in a ledger in a barely legible handwriting. The document reflected his vast biological knowledge and his idea of mutual dependence of vital-units (cells, tissues, organs, organism, communities), either of a parasitic, mutualistic or commensalistic character. This relationship was elaborated in his model of symbiosis. His description of the role of man in *Geobiology* is a personal complaint of a geobiologist over the disastrous treatment of the earth by man. With his concept of "dissipation", he introduced a material analogue for "the entropy lowering capacity of living systems". It summarised his conviction that the human intellect and life condition were attributes of free will. Although *Geobiology* (1944) remained unfinished and had major gaps, it still is an inspiring memoir of a scientist who records his enlightened vision on the relationship between life and earth.

In this issue of *Geochemical Perspectives* the manuscript of *Geobiology* is integrally transcribed, annotated, edited and introduced by Dr. Alexander J.P. Raat, who graduated in 1974 in Leiden as a plant physiologist. The transcript is published with the original illustrations. A sketch of Baas Becking's life and works is part of the introduction. The annotation and introduction refer to many of his published and unpublished studies. Among these is an unpublished, further updated and revised version of *Geobiology*, which he completed in 1953 in Australia.



Ledger Geobiology (1944)

Front pages of the manuscript Geobiology



Left: *Triangular plot in which oxygen and hydrogen are related with carbon to show the chemical processes such as oxidation and reduction, hydrogenation, dehydrogenation, carbonisation and caramelisation. The table summarises for various compounds the number of electrons removed per C atom.*

Right: *The graphical plot gives the stage of reduction E as a function of RQ [Respiratory Quotient] and the number of electrons removed per C atom from carbon compounds such as CO_2 = 0.00 to CH_4 = 8.00. The heat combustion ΔH of a carbon compound is proportional to its stage of reduction E. See Baas Becking (1947b) for explanation. See also Section 3.5.16 and Plate 3.2.*

Transcript of the right page

L.G.M. Baas Becking

1 April 1944 to T.[1]

Concept!
Not to be printed or cited LBB
Written without the aid of literature

Geobiology

1. The problem
2. The Earth
3. The Milieu
4. The Organisms
5. Influence of the milieu upon the organisms
6. Influence of the organisms upon the milieu
7. Mutual influence of the organism.
8. Man and the terrestrial milieu
9. Description of natural milieu.
10. Literature & Tables

7-7-44 bis 25-8-44 Kriegswehrmachtgefängnis Utrecht

"Die Welt is volkommen ueberall wo der Mensch nicht hinkommt mit seiner Qual", W. Goethe.[2]

[The world is all perfect except where man comes with his burden of agony.]

Zur Beachtung [Please note]

Dieses Manuskript ist in englischer Sprache abgefasst weil der Autör eine Kongreszsprache wählen musste um doppelte Arbeit zu umgehen und weil er das deutsche Idiom nicht genügent bewaltigt hat.

[This manuscript is written in English because the author had to choose a congress language to avoid duplication of effort and because he did not adequately master the German idiom.]

L.G.M. Baas Becking

[in the right margin on top of the page, written in pencil in a box and scratched out][3]

Desiderata	De Candolle
Clay	Theft of soil
Gyttja	Soil loss subbrine
Humus	Salt of Boekelo
Galls	Purples under quartz & bluegreens
… – plants	Eye of *Gyrinus*
Serology	Biological self-purification
Organogene	Varves
Dünenbildung	Rice-root

1 Reference to Mrs C.J. ('Tine') Niekerk-Blom, who probably supplied Baas Becking with the ledger when he was in prison in Haaren after his failed attempt to escape to England by boat in April 1944.

2 The quote is from F. Von Schiller, *Die Brand von Messina* (1803).

3 Apparently, this list of subjects was intended as a reminder. The subjects mentioned are discussed or mentioned by Baas Becking in this manuscript of *Geobiology*.

1. THE PROBLEM

1.1 Historical

Man lives on the earth, and although his Kingdom is not of this world, this seems insufficient reason to neglect our relation with our foster planet, which has been, and probably will remain, the sole abode of mankind. As Henderson (1913) pointed out in his masterly essay *The Fitness of the Environment*,[1] current opinion, up to the birth of natural sciences was that the earth was created as our playground, our property, and that all conditions on earth, physical, chemical and biological, were such as to create the best possible of recreation parks of *Homo sapiens*. If this were so, we have cut a rather sorry figure in maintaining this park. Vandals, rotten and wasted, rather than stewards and managers we have been, dissipating this part of our divine heritage at an ever increasing rate.

The dawn of our understanding of geobiology, the relation of living things to the earth, is therefore merely anthropocentric and this is not to be wondered at, as the old religion books, such as *Genesis*, were conceived and inspired when man already began to shape the face of the earth when *the anthropic epoch* had as a toy set in.[2] And this ancient, pre-scientific mode of thinking is still paramount in many people, in folklore not only, but still in living thought. We divide the hood-fungi into "toadstool" (poisonous) and "mushroom" (edible), we speak of "noxious" and "useful" animals, of "weeds", "herbs" and "flowers". An organism should have a "virtue", apart from its bare existence!

I have not been able to cull from the Greek philosophers' dicta about matters geobiological, but remember the saying of Aristotle, "*Man is, by fate, the best-known animal*". The best known [animal] of Aristotle is the unknown [animal] of Carrel (1935)![3] The best known in its taboos, in its nicknames, in its head, in its greed. The unknown [animal] influences however, the unexploited force to their good!

When man began to look around and to recognise objects, it was already late in the day, let us say 17th or 18th century. About 1542 we find Van Helmont,[4] who proved that a willow tree forms itself chiefly out of water and air, then, in the 18th [century] we find Linné who recognised the biological lime deposits (*omne calx ex vivo!*),[5] and later, in 1779, Jan Ingenhousz published his *Experiments Upon Vegetables* in which he proved that green plants, under the influence of sunlight, "improve" the quality of the atmosphere, or as he said "*dephlogistonate*".[6] Lyell expressed his actuality principles in geology.[7] And the concept of evolution increasingly occupied the mind, foregoing a lasting link between geology and biology. Then, by the genius of Pasteur, the universal distribution of microbes through the air was recognised (1860).[8] The sciences of microbiology, grown and tended by Pasteur's loving hands, developed to a great science under

1 Baas Becking referred to Lawrence Joseph Henderson (1878-1942), American physiologist. In 1913, Henderson wrote *The Fitness of the Environment*, one of the first books to explore concepts of fine tuning in the Universe. He concluded: "the whole evolutionary process, both cosmic and organic, is one, and the biologist may now rightly regard the universe in its very essence as biocentric". In the 1953 manuscript of *Geobiology* Baas Becking wrote about Henderson's *The Fitness of the Environment*:

> In his book he stresses the reciprocal nature of "Darwinian fitness", He gives an analysis of the properties of water and discusses other possible environments in relation to cosmogony and to geochemistry. He arrives at the conclusion that the properties of the environment, biologically considered, present the same fitness as the properties of life. His is the first coherent and analytical statement of the relation between the inner world and the outer world. A great many of Henderson's arguments have inspired later workers.

2 Baas Becking's terminology for Anthropocene.

3 Reference to Dr. Alexis Carrel (1873-1944), French surgeon awarded the Nobel Prize in Physiology and Medicine in 1912. He is also known by his book titled *L'Homme, cet Inconnu* [*Man the Unknown*]. In the book, he attempted to outline a comprehensive account what is known and more importantly unknown of the human body and human life "in light of discoveries in biology, physics, and medicine", to elucidate problems of the modern world, and to provide possible routes to a better life for human beings. Carrel advocated, in part, that mankind could better itself by following the guidance of an elite group of intellectuals, and by incorporating eugenics into the social framework. He argued for an aristocracy springing from individuals of potential. Carrel advocated the use of gases to rid humanity of "defectives". For the insane and the criminal, he endorsed the use of gasing for euthanasia. Otherwise, he endorsed voluntary positive eugenics.
In the unfinished manuscript of *The Kingdom of this World* (Baas Becking, 1942-1943) he remarked (p. 2):

> I am aware of the existence of eugenics. Eugenics is not going to help us, even if it were effective. It is not going to help us because it only considers one side of the question. It considers a selection of individuals, which are, in the broadest sense, *capable* of happiness. The happiness, however, is not provided. The factors of the "milieu interne" have to be matched by those in the "milieu externe". And our "milieu externe", our earth, is now almost trodden underfoot by a lot of greedy heedless and headless vandals. So, there will be no place to be happy in. And what are a lot of highly selected "plus-variants" going to do on the rubbish heaps left by those who selected them? We may create men like gods, but we are going to leave them dust and slags to feed upon.

4 Jan Baptist van Helmont (1580-1644), Dutch chemist, physiologist. He was the first to understand that there are gases distinct in kind from atmospheric air.
In his lecture, *De geest uit de kruik*, in the Botanical Laboratory Leiden, September 17, 1932, Baas Becking gave a comprehensive review of the history of photosynthesis research (Baas Becking, 1932).

5 In his 1953 manuscript of *Geobiology* Baas Becking wrote (p. 587):

> For the sediments we may claim;" omne calx, omne carbo, omne phosphorous, ex vivo".

6 Jan Ingen-Housz (1730-1799), Dutch physiologist, biologist and chemist and physician at the Austrian court in Vienna, who discovered photosynthesis. See Magiels (2012, Chapter II).

7 Charles Lyell (1797-1875), Scottish geologist. Baas Becking in his 1953 manuscript of *Geobiology* (Chapter II, p. 59):

> It has been said that the theory of Cuvier, according to which organisms were wiped out at intervals by terrestrial cataclysms, has been satisfactorily countered by the "actuality principle" of Lyell, according to which the same geological forces are at work today as were in the past. The "pulse of the earth" seems to belie this statement. It is not inconceivable that a great "cataclysm" such as an ice age and its preceding and subsequent epochs, may have acted as a powerful stimulant to speciation, apart from the extermination of many less resistant forms. Here some, like Heribert Nilsson, replace the word evolution by "revolution".

Pulse of the Earth published in 1942 by the Delft geologist Jan Herman Frederik Umbgrove (1899-1954). He was a former pupil of the Leiden geologist Professor Berend George Escher (1885-1967).
Nils Heribert-Nilsson (1883-1955), Swedish botanist and geneticist, whose *Synthetische Artbilding* (1953) was summarised in *Science* (1954, v. 120, p. 257-258) by Joel Hedgepeth:

> The concept of evolution as a continuously flowing process can be proved only on Lamarckian lines, since "evolution and Lamarckism are inseparable because they include the same fundamental ideas." There is no proof from the data of genetic recombinations or mutations to support the generally accepted concept of evolution; therefore, evolution is not occurring at this time. Nor does it seem to have occurred in the past, since the fossil record is the result of piling up and preservation of world biota during the periods when the nearness of the moon induced tremendous tidal action (the "Tethys Sea") and freezing at high latitudes because of the pulling of air toward the equator hastened such preservation. During these revolutionary periods there was resynthesis of the entire world biota by gene material or gametes along the same basic lines (hence, there is no point to phylogenies, since the similarities of organic life are due to the synthetic activity of similar "gametes"); this process is termed "emication".

8 Louis Pasteur (1822-1895), French biologist, microbiologist renowned for his discoveries of the principles of vaccination, microbial fermentation and pasteurisation. The reference is to Pasteur (1861). See also Section 4.3.3.

his followers Winogradsky and Beijerinck.[9] "*L'influence des êtres infiniment petits paraît infiniment grande*", says Pasteur. Physiology of plants and of animals, biochemistry and genetics define the position of living things in the general scheme of this world.

Now, in the nineties, there stand recorded an experiment of Martinus Willem Beijerinck, which gave the clue and the key to a great biological problem, that of distribution and that of dispersal. Already in 1842 Goodsir had observed, in the stomach of a person suffering from gastric ulcer, a so called packet bacterium *Sarcina*, which he called *Sarcina ventriculi*. Beijerinck isolated the same *Sarcina*, more than fifty years later from ditch water. This on itself is not so remarkable as the method of thought underlying this experiment. Beijerinck created, one by one, in his culture vessel, the conditions, the "milieu factors" characteristic of a mammalian stomach, to writ 1) anaerobic, 2) high acidity, 3) 37 °C, 4) high concentration of organic substrata.

Beijerinck has asked a definite question. Which organism resonates with the given environment? Which organism, amongst the thousands of various latent spores and germs, will show itself and multiply as a counter world of the culture solution provided. In this experiment, like in a huge number of other isolations performed by this great biologist, these are underlying thoughts, as I said, of the greatest importance. The first is the conviction that all species of microbes occur everywhere and the second is that, although these microbes are everywhere a specific milieu will select a specific organism from the large mass of latent life. These rules, to which I have given the name of Beijerinck's rules, may be briefly (although not quite correctly) summarised as "*Everything is everywhere* and *the milieu selects*".[10]

Let us name another experiment of Beijerinck. A slice of white bread is put under the steady trickle of a tap, not directly under the tap, but so that the "splash" wets the bread. After a week or so at room temperature a beautiful violet bacterium, *B. violaceum* develops (Derx, oral communication).[11] Still another example; a mineral agar is prepared and poured into a plate. Care is taken to omit nitrogen compounds. The plate is inoculated with garden soil suspension and placed in the light. Bluegreen algae develop, that need light for development, but are able to fix atmospheric nitrogen! The numbers of examples are legion. The whole process of enrichment cultures is based upon Beijerinck's rules (see also Stockhausen).[12]

The universal dispersal of organisms is of the greatest importance to geochemistry, a fact already recognised by Charles Darwin. Geobiology deals with the interplay of forces; animate and inanimate. Strictly speaking, it should include the history of mankind as well, as far as it is concerned with the shaping of the earth. It is difficult, in the drama of geobiology, to separate the stage from the actors. Still more difficult it is to tell the hero from the villain. Maybe there are no heroes and no villains. The stage of the drama we shall call the milieu, and the actors, the living beings, are driven by their environment and by their inner; say, by nurture and by nature, by "nourriture et nature". Their environment is part animate and part inanimate. In order to evaluate their influences, a great many data were needed. Geochemistry as a separate discipline came into being in this century (Vernadsky, Day, Clarke, Goldschmidt).[13] The concept of milieu, initiated by Yves Delage[14] and by Claude Bernard,[15] has been much more clearly defined in the last decades. The mutual relation of organisms has been better understood since the discovery and ever increasing knowledge of vitamins,

9 Martinus Willem Beijerinck (1851-1931), Dutch microbiologist and botanist, one of the founders of virology and environmental microbiology.
Sergei Nikolaievich Winogradsky (1856-1953), Russian microbiologist, ecologist and soil scientist. The reference is to Winogradsky (1888). *Beitrag zur Morphologie und Physiologie der Bakterien.*

10 Baas Becking used the word 'milieu' instead of 'environment'. In the 1953 version of *Geobiology* Baas Becking added to "Everything is everywhere" (p. 135): "(organisms such as oak trees and lions excepted)". According to Baas Becking the ubiquity rule:

> Holds both in nature and in the laboratory. The better defined the question, the sharper the answer. A very specific milieu, an extreme milieu (whether extreme in temperature, acidity or salt content) will sharply define a group of organisms occurring therein; whether bacteria, bluegreen algae, amoebae, flagellates or ciliates. But field ecology alone will never be able to give a complete answer as to the possible resonance of living systems and a given milieu; this answer is the prerogative of the laboratory.

See for Baas Becking's 'ubiquity law': De Wit and Bouvier (2006), O'Malley (2007) and O'Malley (2008).

11 Reference to Henri George Derx (1894-1953), a friend of Baas Becking since his study in Delft. During WWII Baas Becking worked as a colleague of Derx in the Unilever Laboratory in Rotterdam (1942-1944). After the war Derx was member of the staff of the Buitenzorg Gardens as Head of the Treub Laboratory. In 1950 he returned to Patria where he worked as advisor for the Dutch Royal Shell Company. In the preface of the 1953 manuscript of *Geobiology* Baas Becking mentions Dr. H.G. Derx and Mrs. C.J. Blom having "done so much that they almost might be considered as co-authors (p. 2). September 1, 1950, Derx was appointed Extraordinary Professor of Microbiology at the Agricultural Faculty at Buitenzorg (Bogor), Indonesia (*Java-bode* 21-11-1950). March 2, 1951, he returned to Patria with the Rotterdamsche Lloyd *Willem Ruis* (*Trouw* 28-02-1951).
Baas Becking wrote a necrology of Derx in 1954.

12 Stockhausen (1907). Baas Becking also referred in *Geobiologie* (1934) to Stockhausen.

13 Vladimir Ivanovich Vernadsky (1863-1945), Russian mineralogist and geochemist, provided the first definition of geochemistry in 1910 and therewith the basis of the scientific discipline concerned with the processes governing the distribution of the elements in the earth system. He is most remembered for his books *Geochemistry* and *The Biosphere*, first published in Russian in 1925 and 1926. Baas Becking (1927) quoted from the French edition of Vernadsky's *La Géochimie* (1924) in his inaugural lecture in Utrecht on October 3, 1927.
Frank Wigglesworth Clarke (1847-1931), chief chemist to the U.S. Geological Survey (1883-1925), one of the founders of Geochemistry. Baas Becking referred in *Geobiologie* (1934) and in this manuscript of *Geobiology* to the third edition of Clarke's *The Data of Geochemistry* (1916), first published in 1908. Apparently, the 1916 edition of Clarke's *Data* was available to Baas Becking in prison. The *Data* remained in his possession all his life, in Baas Becking, Kaplan and Moore (1960) he still referred to Clarke (1916).
Victor Moritz Goldschmidt (1888-1947), Norwegian mineralogist considered together with Vladimir Vernadsky to be founder of modern geochemistry.
"Day" not identified, possibly Baas Becking referred to the Scottish chemist and geologist Thomas Cuthbert Day (1852-1935).

14 Yves Delage (1854-1920), French zoologist, director Station Biologique de Roscoff since 1901. He considered how life in individual organisms and species is manifested through cytoplasm. He became strong proponent of the neo-Lamarckian view of heredity and evolution. He received the Darwin Medal in 1916. See also Sapp (1994, p. 94-95).

15 Claude Bernard (1813-1878), French physiologist. Milieu intérieur is the key process with which Bernard is associated:

> The living body, though it has need of the surrounding environment, is nevertheless relatively independent of it. This independence which the organism has of its external environment, derives from the fact that in the living being, the tissues are in fact withdrawn from direct external influences and are protected by a veritable internal environment which is constituted, in particular, by the fluids circulating in the body.
>
> The constancy of the internal environment is the condition for free and independent life: the mechanism that makes it possible is that which assured the maintenance, within the internal environment, of all the conditions necessary for the life of the elements.
>
> The constancy of the environment presupposes a perfection of the organism such that external variations are at every instant compensated and brought into balance. In consequence, far from being indifferent to the external world, the higher animal is on the contrary in a close and wise relation with it, so that its equilibrium results from a continuous and delicate compensation established as if the most sensitive of balances.

See Claude Bernard (1974, p. 84).

hormones and other ergones.[16] Geology, almost grudgingly is given an increasing amount of room in the textbooks to topics biological (outside *Foraminifera* and other fossils), although, even in recent books, one meets many biological heresies.

The role of the atmosphere in the dispersal of living matter, already recognised by Pasteur, has been, in recent years, repeatedly investigated. Water analysis, since the publication of the data of geochemistry, has founded new paths. We are justified in saying that it seems not too premature to endeavour to link up the data obtained from several fields and try to form a synthetic picture, which we might call geobiology. As this geobiology is written by a biologist, there is a decided bias to the biological side. The author offers no apology for this tendency. The discipline described here as the crossroad leading to a great many sciences, and although many seductive paths lead into one or the other realm, it seemed safer to keep to the biological highway. And when the writer has strayed, it was to return to this highway with the conviction that the key to geobiology lies in biology itself.

1.2 Ecology

[Ecology] literally the knowledge of the oikos, of the house. The house being the earth. Actually, it describes the relation of land organisms to this environment. Ecology in the broadest sense embraces at least eight sub-divisions (Table 1.1), to wit:

Table 1.1 Division of ecology, in which each biological group is named before its physical chemical counterpart.

1. Ecology s.s.	→ 1a Soil sciences s.l.	↗ Microclimatology → Pedogenesis ↘ Agrogeology
2. Hydrobiology	→ 2a Limnology	
3. Marine biology	→ 3a Oceanography	
4. Aerobiology	→ 4a Meteorology	

1.2.1.a *Ecology in the strictest sense*

Ecology. [Ecology] deals with terrestrial organisms (Elton, Clements, MacDougall, Cooper).[17] It is concerned with the adaptation to certain environments, with the character of vegetation and forma in these environments, without further query into their causes. In the botanical ecology we recognise for instance hydrophytes, plants growing in a humid atmosphere and their opposites xerophytes, plants growing in a dry environment. Then there is the great group halophytes, salt-loving or salt-tolerant plants, also the rheophytes, plants growing on very steep inclines. Finally, epiphytes, plants growing upon other plants. In animal ecology we might create a similar series.

This section should of course be very much extended. Having for the epiphytes the recent monograph of Went,[18] for the halophytes Ruhland and Montfort,[19] for the xerophytes Walter[20] for the hydrophytes Glück, Troll, Shelford.[21]

Synecology, vegetation types and groups. Schools of Blytt-Sernander[22] and of Braun-Blanquet.[23] Plants and animals occurring together have formed the object of much literature which is, as far as I can see, chiefly nomenclatorial. As long as this branch of ecology remains in that state many of us seem to be totally unimpressed to it. A word for instance is *Carpinion-Betuletum*, but neither *Carpinus* nor *Betula* need to occur there.[24] Synecology when viewed from the point of view of symbiosis (Funke) may be very useful,[25] but that facts and experiments should take the place of mere verbosity. It appears that Braun-Blanquet from Montpellier goes the furthest in thorough division of vegetation types.

Biogeography. Apart from its use in distribution the “area” concept has been developed, usually in combination with geological speculation (Wegener, Vening Meinesz, Holmes).[26] Biogeography has been of great service in phylogeny, in geomorphology and in the part of ecology that deals with the distribution of organisms. Alexander von Humboldt initiated this science in the beginning of the 19th century.[27] It has been part of ecology from the very beginning, especially after the appearance of the treatises

16 Ergones are inorganic and organic substances acting as activators in the living cell, enzymes and vitamins. Euler (1938). *Bedeutung der Wirkstoffe (Ergone), Enzyme and Hilfsstoffe im Zellenleben.* In his 1953 manuscript *Geobiology* (p. 634), Baas Becking described ergones as ‘organic minimum substances’.

17 Baas Becking referred to Charles Sutherland Elton (1900-1991), English zoologist and animal ecologist, published *Animal Ecology* in 1927; Frederic Edward Clements (1874-1945), American plant ecologist; Walter Byron McDougall (1883-1980), American ecologist, published *Plant Ecology*; William Skinner Cooper (1884-1978), American ecologist.

18 Frits Warmold Went (1903-1990). Dutch biologist, son of Baas Becking’s PhD supervisor F.A.F.C. Went. Baas Becking referred to Went F.W. (1940). According to Wolf, Gradstein and Nadkarni (2009):

> In his classic study on the sociology of epiphytes, Went (1940) described the canopy by lying, face-up, with field glasses on a stretcher, while field assistants transcribed his spoken observations. Plants fallen to the ground and local tree climbers provided voucher collections. Although these techniques seem primitive compared with those used by modern canopy scientists, much of our knowledge of epiphyte distribution is still based on this type of data.

19 Eugen Otto Wilhelm Ruhland (1878-1960), German botanist and plant physiologist. Baas Becking possibly referred to Ruhland (1915) and Montfort and Brandrup (1927).

20 Heinrich Karl Walter (1898-1989), German-Russian Geobotanist and eco-physiologist. He received a Rockefeller Fellowship (1929-1930) for the exploration of desert plants. In the 1920s and 1930s he published several studies about the adaptation of plants to lack of water and ecological studies of plants in the African savannes.

21 Hugo Glück (1868-1940), German botanist, published (1905-1911) *Biologische und Morphologische unersuchungen über Wasser- und Sumpgewächse.*
‘Troll’ possibly Julius Georg Hubertus Wilhelm Troll (1897-1978), German plant morphologist, who published (1937-1942), *Vergleichende Morphologie der Höheren Pflanzen.*
Victor Ernest Shelford (1877-1968), American zoologist. Baas Becking referred to Shelford (1929).

22 The Blytt-Sernander classification, or sequence, is a series of north European climatic periods or phases based on the study of Danish peat bogs by Axel Gudbrand Blytt (1843-1898) and Rutger Sernander (1866-1944). The classification was incorporated into a sequence of pollen zones later defined by Lennart von Post (1884-1951), one of the founders of palynology.

23 Josias Braun-Blanquet (1884-1980). He developed a cover abundance scale for vegetation analysis in land development studies.
For a contemporary criticism of the “flora elements” according to the definition of Braun-Blanquet, see Heimans (1939). Heimans objected against the inclusion of sociological plant communities together with plant species in the same group. Possibly Baas Becking’s remark about Braun-Blanquet was inspired by reading Heimans study.

24 Vegetation type *Carponium-Betuletum*, also *Carponium-Betuli*.

25 Baas Becking referred to Funke (1943). In this article Funke described the negative effects on germination and development of plants by the excretion of absinthian.

26 Alfred Wegener’s (1880-1930), author of *Die Entstehung der Kontinente* (1912). The reference is to the continental drift controversy. Arthur Holmes (1890-1965) supplied geological evidence for the theory. The Dutch geophysicist Felix Andries Vening Meinesz (1887-1966) questioned the plausibility of positing large scale convection currents to endorse mobilism as defended by Holmes. See Frankel (2012).

27 The reference is to Alexander von Humboldt’s (1769-1859) *Essay on the Geography of Plants*, published in 1807 in German and in French. The *Essay* introduced his ideas on plant distribution and nature as a web of life. See Wulf (2015).

by Schimper[28] and by Warming.[29] The original concept of the relation between climate and vegetation type, a purely ecological concept, is certainly von Humboldt's.

1.2.1.b Soil science s.l. [in the broadest sense]

(Russell, Waksman, Tolman).[30] Soil is facies of weathered, often sedimentary rock with specific chemical and physical properties, which make it fit for the rock milieu of terrestrial plants.

Microclimatology. Ecologically the atmosphere in contact with the soil belongs to soil science. As official meteorology starts at the 6 ft level, the intricate, microclimatological changes are lost to meteorologists. Microclimatology deals with the climate in very small areas, with inclusion evaporation, wind velocity, temperature, humidity *etc*. and their gradients in and near the soil (Pinkhof).[31] Here we find heterogeneity and extreme values, but values of primary importance to the vegetation. The same cannot be said of the official weather report data.

Pedogenesis.[32] This is part of ecology (Correns, 1939) but for the organic part;[33] the humus. The origin of humus (Waksman) is one of the most important parts of pedogenesis. We mention, furthermore, such problems as poor exchange, grain size and its distribution, pedolisation and lateralisation.[34] By description of these phenomena a natural classification of soils results. The problem of synthetic soil has as far as I am aware not been sufficiently attacked. The author can find no word to describe the biological counterpart of this purely non-biological microclimatology and petrogenesis.

Agrogeology is certainly not right, because he (= Correns, 1939) wants to embrace all types of soils. The bacteriology and geobiology of plant and animal should be dealt with here. It seems a wonderful chance for somebody to systematise the enormous mass of data on the subject already existent.

1.2.2 Hydrobiology

(Founded by Forel, the classic is named "Le Leman").[35] The biological part we shall call hydrobiology, the environmental part limnology, occurring in water in ecological classes. The biological part first classifies types of organisms:

a. ***Higher aquatic, floating, or rooted in the soil***. In the latter case we meet with the problem of oxygen transport (Roodenburg for *Nymphaea*, Van Raalte for *Oryza*).[36] Glück has given a biological description of higher plants.[37]

b. ***Plankton***. The more or less floating microscopic animals and plants, show a world of special biological characteristics. They influence the water to a high degree, they are influenced by the water equally markedly, diversity, light transmission and the physical factors play a large role here. Plankton, in many cases may also enrich water with certain (not all minimum) compounds (Wesenberg-Lund, Atkins, Shelford, Ward, Whipple, Ringer, Juday, Ruttner, Thienemann).[38]

c. ***Nekton*** floats on the surface. It suggests its special problems, especially of what the author called "planonts", beings living in the extreme surface layer and only to be studied by special methods.[39] From ducks to mosquito larvae, and from mosquito larvae down to bacteria. Often,

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28 Reference to Andreas Franz Wilhelm Schimper (1856-1901), German botanist and phytographer, author of *Pflanzengeographie auf Physiologischer Grundlage* (1898).

29 Reference to Johannes Eugenius Warming (1841-1924), Danish botanist, who published in 1909, *Ecology of Plants: an Introduction to the Study of Plant Communities*.

30 The reference to 'Russell' is to Sir E. John Russell (1872-1965) and his son E.W. Russell. They published *Soil Conditions and Plant Growth*, in 1912 (many editions afterwards).
'Waksman' refers to Selman A. Waksman (1888-1973) for his work the microbiological population of the soil, sulphur oxidation by bacteria, microorganisms and soil fertility, decomposition of plant and animal residues, nature and formation of humus. Waksman was winner of the 1952 Nobel Prize in Physiology or Medicine "for the discovery of streptomycin", later corrected "for ingenious, systematic and successful studies of the soil microbes that led to the discovery of streptomycin". The correction of the wording was because the role of the co-discoverer of streptomycin Albert Israel Schatz (1920-2005) was not recognised.
'Tolman' is Cyrus Fisher Tolman (1873-1942), Professor of Economic Geology at Stanford University (1912-1938), who initiated a programme in *Ground Water* at Stanford. Baas Becking possibly referred to Tolman (1937).

31 Possibly reference to Marianne Pinkhof who published in 1929 a PhD Thesis *Untersuchungen* über *die Umfallkrankheit der Tulpen. Recueil des Traveaux Botanique Néerlandais*.
In 1934 she calibrated Baas Beckings AMALUX light meter. Postcard Plantenphysiologisch Laboratorium Universiteit Amsterdam, April 2, 1934 (AAS Basser Library Ms. 043 nr. 130-5).

32 Pedogenesis (also termed soil development, soil evolution, soil formation, and soil genesis) is the process of soil formation as regulated by the effects of place, environment, and history. Biogeochemical processes act to both create and destroy order (anisotropy) within soils. These alterations lead to the development of layers, termed soil horizons, distinguished by differences in colour, structure, texture and chemistry. These features occur in patterns of soil type distribution, forming in response to differences in soil forming factors.

33 Carl Wilhelm Correns (1893-1980), German professor of mineralogy and Geology at Rostock and later at Göttingen. In 1926-27 he participated in the German Atlantic Expedition on board the M.S. *Meteor*, to collect and investigate deep sea samples from the southern Atlantic. Correns was one of the founders of modern sedimentary petrology, which deals with the identification of sedimentary minerals and the explanation of the phenomena of weathering, sedimentation, and diagenesis by physicochemical processes. Baas Becking referred to Correns (1939), *Die Entstehung der Gesteine, ein Lehrbuch der Petrogenese*, p. 174. He had a copy of *Die Entstehung der Gesteine* in the Utrecht prison, that he received on July 5, 1944, from Mrs. Tine Niekerk-Blom. NIOD 214, nr 33.

34 Lateralisation are soil forming processes. Lateralisation is tropical weathering, a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore mineralogy of the resulting soils.

35 François-Alphonse Forel (1841-1912), pioneer of the study of lakes. Baas Becking (manuscript *Geobiology* 1953, Chapter IV, p. 287) considered Forel "founder of modern limnology". His chief work is the three volume of *Le Leman* (1892-1904). In his 1953 manuscript *Geobiology* Baas Becking opened Chapter V with a quote from Forel's *Le Léman*:

> La description de la terre n'est pas l'énumération et la description individuelle de chacune des catégories d'êtres et de choses. Qui se rencontrent sur notre planète, c'est plutôt le tableau d'ensemble, offert par la réunion de ces diverses catégories, par leurs rapports les unes avec les autres, par les réactions quelles reçoivent du milieu dans lequel elles sont plongées, et qu'elles produisent sur ce milieu. Forel, *Le Léman* 1892.

36 Reference to Roodenburg (1927). Baas Becking in his 1953 manuscript *Geobiology*, Chapter IV, p. 303, summarised:

> Higher plants like Nymphaeaceae may root in 30 ft deep water. Their roots are supplied with oxygen taken in by the leaves, and conducted by intercellular spaces.

Maurits Henri van Raalte (1907-2002) studied in 1939-1942 the oxygen supply of rice roots in the low oxygen conditions of the sawah soil in the Treub laboratorium of Buitenzorg. Baas Becking was evidently aware of the results of his study before they were published. Reference to Van Raalte (1941). In the Baas Becking *Geobiology* manuscript 1953, Chapter IV, p. 303, summarised:

> Van Raalte has been able to show that the rice plant also actively conducts air to the roots, where it may be excreted into the black mud causing the formation of ferric hydroxide.

37 Reference to the three volumes of Glück (1905-1911).

38 References to Wesenberg-Lund (1895/1904), Ward and Whipple (1918), Shelford (1911a, 1911b), Atkins (1916) and to Franz Ruttner (1882-1961), limnologist. Author of *Grundriss der Limnologie des Süsswassers* (1940). See also Section 3.5.9.

39 The term "planont" is nowadays used for motile cells produced and released from sporangia of the entomogenous fungus *Coelomomyces*, aquatic insect pathogens, the majority of which effect mosquitoes. The planonts develop in the hemocoel of infected insect larvae and are essential in the disease development of the infected insects. See Madelin and Beckett (1972).

we meet with epidermitis, the causes of which are often imperfectly understood (See however v. Heusden),[40] …., *Diatomea*, *Peridinium*, *Chlamydomonas* or bluegreens, "waterblow". This is especially important for waterworks and swimming pools.

d. At the bottom we find ***Benthos***, chiefly animal in nature and living from the planktonic and nektonic debris roaming clones continually. Here we find animals with haemoglobin, detritus eaters as rotifers. Here we often find the curious community attracted by, or able to withstand hydrogen sulphide. Benthic organisms form some very good soil, maybe they also form the mother-like substance in the genesis of oil (epibiosis).

e. Further ***E[va]porites***, that grow upon rocks, bridges or other organisms.[41] Some of them make a current of water; others need living water (rheobionts as *Hydromus*). In small bodies of water nearly all of the organisms may belong to this group among which we mention bacteria, protozoa (*Vorticella* ….) diatoms, bluegreen and green algae *etc*.

f. ***Special communities***. Special environments yield special communities. Hot springs, brackish waters and brines, acid waters or volcanic lakes all harbour special biocoenoses. The similarity between the several extreme communities is often striking. It seems that one meets the same actors at the exposed places. Naturally hydrobiology should take into account the bacteriological changes in its waters and in its sediments.

g. ***Sediments***. However, the bacteriology of the mud shows the "gyttja" is still in its infancy.[42]

1.2.2.a Limnology

[Limnology] is the physical, chemical and geological counterpart of hydrobiology. It is, in the first place, concerned with the properties of water and how these properties show themselves in rivers, ponds, lakes and springs. In the latter part of the 19th century water analysis gave us knowledge of the:

a. ***Chemistry of natural waters***. The data obtained admit of certain interesting generalisations. It appears that there are a limited number of types of natural freshwaters and that other types, chemically equally probable, or not seem to occur.

b. ***The physical properties of water***, of course exert a great influence upon the living beings in the water. Some of these properties, like the absorption of radiation, have been studied chiefly under the influence of hydrobiology (Atkins). Others, of purely academic intent may become important later.

c. ***Physics and chemistry of large bodies of water***. The maximum density of freshwater at about 4 °C causes intricate and entirely vertical currents to occur in deep masses of water. This is an example of the application of a physical principle. Chemical changes as well may be traced (Birge and Juday, 1926).[43] They are, usually of biological origin.

d. ***Configuration of the bottom sediments***. Lakes and pond deposits, chalybeate,[44] lime or marl, or chiefly organic [substances], are an important part of limnology, not interesting only to the geologist, but to the agronomist and the bacteriologist as well. Here we often meet with periodic phenomena, and so called "varve" formation.[45] We know;

e. ***Eutrophic waters***, of an acidity and further chemical composition that enables copious development of different groups of inhabitants. Chemical factors are usually at the minimum for a very short time.

f. ***In oligotrophic waters***, however, the nutrient salt contents as different and minimum phenomena may become chronic. Rheophilics often may hold out longest (mountain streams).[46] These are:

g. ***Dystrophic environments***, where high acidity, high alkalinity, high temperature or hydrogen sulphide or the lack of oxygen causes a diminution of the less hardy. Amongst these we mention:

h. ***Saline environment***, a very specific milieu, widespread and hydrobiologically most interesting, as it challenges our cherished so called fundamental laws of physiology. The weird living circumstances of the strong brines is described in Section 3.13.5; 4.3.9 and 5.2.4, also:

i. ***Hot springs*** deserve special mention as here we find communities very similar to those in the brines. Out of a great many further limnological problems we arbitrarily select:

k. ***The origin of waters***. Really, we should have started with this question, as there is no life and no hydrobiology without water. There is: vadose from the soil, juvenile from deep in the earth, meteoric from the atmosphere, metabolic from the decomposition of organic matter (see Section 3.5.18).

1.2.3 Marine biology and oceanography

There is of course a close relation with hydrobiology, of which both parts are, apparently not quite aware. All that has been said under hydrobiology pertains, apart from the fact that, although seawater covers 2/3 of the surface of our globe. The chemistry of seawater and physics of seawater are remarkably constant, so enduring we nowhere find a set of conditions on the whole earth. Our scope is, at the other hand, greater, for the expanse is vast. Pressure effects and light penetrations we may study from the depth of 10000 metres. Oceanographers have paid attention to influence of terrigenous material.[47] This is, especially at the estuaries of rivers, of great importance. Frozen rivers, glaciers, may also carry enormous amounts of material. The whole problem of the charge river-sea enters here into play. More typical and

40 Reference to Dr. G.P.H. van Heusden biologist of the Amsterdamse Waterleiding. See also Section 5.9.3.

41 'Eporites', unknown term. Baas Becking evidently referred to *Evaporites,* major coral components of reefs, both in the fossil record and in living reefs, in which they can be the most important framework builder. See also Baas Becking, Kaplan and Moore (1960).

42 For 'gyttja' see *Geobiologie* (1934, p. 166-167) and *Geobiology* (2016, p. 88).
Dead organisms, calcium carbonate, fine particles of clay and sand etc., will slowly sink into the hypolimnion and produce mud or gyttja.
See also Correns (1939, p. 175, 210, 247, 248).

43 Refers to the studies of Edward Birge (1851-1950) and Chancey Juday (1871-1944) on the Madison Lakes especially in Lake Mendota (Birge and Juday, 1911, 1926).

44 Chalybeate waters, also known as ferruginous waters, are mineral spring waters containing salts of iron.

45 A varve is an annual layer of sediment or sedimentary rock.

46 See also Baas Becking (1953a) manuscript *Geobiology* Chapter IV, section *Oligohalitic communities*, p. 280-281.

47 In oceanography terrigenous sediments are those derived from the erosion of rocks on land.

even more important, is the configuration of the bottom, a study of which has in the last decades (*Meteor*, Wattenberg; *Snellius*, van Riel),[48] yielded very important results. Part of the sedimentation problem enters here. The chief problem for the oceanography lies in the vertical and horizontal.

Current Bjerknes theorem,[49] salinity and temperature being measurable entities fit to calculate the movement of the water. Oceanic currents are, at the other hand, a counterpart of the planetary rotation (precipitation, monsoons), which will be mentioned elsewhere. One of the chief shapers of brine depositions, has been studied extensively. It covers reef formation, *foraminifera* ooze,[50] cocoa lithosphere.[51] Also the silica, the iron, the phosphate and the manganese deposition enter into play.

The problem of tides and waves although of great interest, rather lies outside the scope of modern oceanography. In marine biology it is again the plankton, which are of paramount importance, especially for the fisheries. The role of the evaporites is much less great, although the fouling of ships and dolphins takes place under their influence.[52] High sea or pelagic forms are contrasted with neritic, which stay in the neighbourhood of the land. Nekton is much richer than in freshwater, due to participating *molluscs*, worms and other animals. The same can be said of benthos, which especially in the neritic zone, is of marine biology. Life cycles of fishes (eel; Joh. Schmidt),[53] as it is connected with the intricate habits of the organism as well as with the multiple complexity of the milieu (Gulf Stream, floating of freshwater on brine). The distribution of organisms in oceans is a special science. It is interesting to see that certain groups preponderate while others are virtually or almost absent (*Amphibia*, *Molluscs*). The origin of the ocean much speculation exists. It may not be a mere solution of primitive rock, probably deep going biological influences have played a role here. According to some we carry, in our blood serum, some "primitive ocean water".[54]

1.2.4 Aerobiology and metereology

Leeuwenhoek ±1700 and later Pasteur ±1860,[55] recognised that the air carries life in the form of spores of aeroplankton, as it was called by H. Molisch,[56] Miquel, and later Lindbergh and Miss A. van Overeem who have made a careful study of this group of organisms. There are fully developed aphids, beetles and flies at 15,000 ft elevation, there are plenty bacteria moulds, especially at cloud bases. At our laboratory we raised a fern (*Athyrium filix femina*) from a spore caught at 4,500 ft elevation![57] Mosses are also very common. These organisms are carried by air currents, and the distance they may travel this way is subject to certain laws (Humphreys, 1920; Correns, 1939).[58] Horizontal currents occur both cyclonal and semi-cyclonal. They distribute soil and volcanic ash over tremendous distances, often within a few months traveling across the entire globe. The organisms are brought at sometimes almost stratospheric elevation by vertical currents, cumulus formation, with willing whirlwinds or ascending air over a volcano. Modern meteorology helps us to trace the amount of air studied. The ecology of the air, also in view of the pollution problem, is hardly studied (Jacq).[59]

1.2.5 Summary and conclusions

What is common to the disciplines mentioned above? We have, apparently, gathered an impressive amount of data on the counter mould, or the "oikos" of life. Cataloguing and classifying we have discovered that the environment fits the organism (Henderson, 1913). We think this the best of all possible results for the terrestrial organisms that we know. This point of view pertains as long as we do not supplement our observation by experiments, as long as we do not study the possibilities of an organism in the laboratory. This of course, is not an easy thing to do, but taking into account most of the sources of blunders already made, we shall see *that the pollution of the organism exceeds that of the natural milieu in many instances.* We shall see further that there is resonance between

48 Reference to the German Meteor oceanographic Expedition (1925-1927) that explored the South Atlantic coast from the equatorial region to Antarctica, in which the chemist H. Wattenberg participated. The Dutch Snellius oceanographic expedition in waters of Eastern Indonesia took place under the leadership of P.M. van Riel (July 1929-November 1930).

49 Two lines of thinking concerning fluid rotation—using either vorticity or circulation—emerged from the nineteenth century work of Helmholtz and Thomson (Lord Kelvin), respectively. Vilhelm Bjerknes introduced an extension of Kelvin's ideas on circulation into geophysics in his paper (1898) *On a Fundamental Theorem of Hydrodynamics and its Applications particularly to the Mechanics of the Atmosphere and the World's Oceans*, what has become known as the 'Bjerknes circulation theorem.' See Thorpe, Volkert and Ziemianński (2003).

50 Foraminiferal ooze is a calcareous sediment composed of the shells of dead *Foraminafera*.

51 Possibly a reference to the convection currents in the semifluid asthenosphere that push and drag the crustal plates of the lithosphere.

52 Baas Becking used the Dutch word 'Dukdalf' instead of the English 'dolphin', a post for mooring boats.

53 Reference to Johannes Schmidt (1877-1933), Danish biologist credited with discovering that eels (*Anguilla anguilla*) migrate to the Sargasso Sea to spawn: Schmidt (1923). See also Section 4.9.5.

54 Reference to McClendon in Chapter IX *Geobiologie* (1934) see English edition *Geobiologie*, 2016, p. 96-97 and p. 100-101. In the 1953 manuscript of *Geobiology* (p. 487-488) the topic is also discussed. See also Section 5.7.4.

55 Baas Becking in his 1953 manuscript of *Geobiology*, Chapter II, p. 133, section, *The Distribution of Life on this Planet*, added a motto from Antonie van Leeuwenhoek (1676):

> "The rainwater, which has been lifted up by the movement of the sun and made the clouds, is mixed with the seed of little animals." On p. 140 he referred to "Louis Pasteur in his 1861 "*Mémoir sur les Corpuscules Organisés qui Existent dans l'Atmosphère*", who first proved the existence of living germs in the air".

In 1924, Baas Becking (1924a) published, in the *Scientific Monthly*, Antonie van Leeuwenhoek, immortal dilletant (1632-1723).

56 Reference to Hans Molisch (1856-1937), Czech-Austrian botanist. From 1922-1925 he was a professor at the Tohoku Imperial University at Sendai, Miyagi, Japan. Baas Becking met the charming "Hofrat" Molisch in March 1925 in Palo Alto:

> Professor Peirce and I had a very pleasant impression of Molisch, who returned from Sendai to Vienna. German speaking members of the department were extremely liebenswürdig to "Hofrat" Molisch, he hooked each of us under one arm and talked non-stop. It was sweltering, and he looked very uncomfortable in a thick black suit, high stiff collar, revealing a thick jaeger shirt. We got him in a real American ice cream parlour. As befits a good Wiener, he looked more at the "Zweibeinige Grazien" than at the ice cream. He carries his 68 years with honour and is still full of plans.

Letter Baas Becking to F.A.F.C. Went, Palo Alto April 5, 1925. F.A.F.C. Went archive, Library Boerhaave Museum Leiden.

57 This passage and the references are taken from the 1937 Leiden PhD thesis of Marie Antoinette van Overeem (1909-2004). In his 1953 manuscript of *Geobiology*, Chapter II, p. 144-145, Baas Becking described the work of Miss A. van Overeem that "yielded the first authentic case of a culture of a vascular plant from an air borne spore". Baas Becking mentioned "the isolation and successful culture of a fern, *Athyrium filix-foemina* L., from an altitude of 1500 ft over central Holland". See also Sections 4.3.5 and 4.3.6. and Visch-Van Overeem (1972).

58 Reference to William Jackson Humphreys (1862-1949), American physicist and atmospheric researcher. His *Physics of the Air* was first published in 1920. Baas Becking further referred to the sections in the section *Transport und Ablagerung* in Correns (1939, p. 132-150).

59 'Jacq' is Nikolaus Joseph von Jacquin (1727-1817).

specific environment and specific organisms. And it shall also appear that the organism exerts a profound influence on the morphology and on the metabolism of the earth's crust.

1.3 Innenwelt and Umwelt

Von Uexküll has created in animal ecology, these terms [Innenwelt and Umwelt] which, in a sense cover our concepts of "milieu interne" and "milieu externe".[60] However, there are differences. While Von Uexküll includes in the "Umwelt" also the "psychical picture" the animal forms of its environment, we shall exclude this factor, in so far it has no material influence upon the environment. Study of "Innenwelt" and "Umwelt" is greatly hampered by the fact that in biology, even more as in physics, the problem of "non-interference" enters in. When we observe an organism, we are in most cases, already interfering. And we are interfering grossly when we experiment with it, when we tear it out of its milieu, culture it by itself on a sort of synthetic food, place it on a microscope slide (the milieu of which may be toxic), or on a jelly-like agar which it never dreamed of. Even if we observe from upon, we interfere. Therefore, for biology, as well as for medicine, the dictum applies "experimentia fallax" [deceptive experiment].

From a lot of circus animals, we cannot learn much about the "Umwelt" of the lion. We may learn something about the lion (inclusive the thorn on his tail),[61] but the lion in its completeness we never meet in the circus. An animal or a plant as they actually live, we never meet in the laboratory. There will be a time when we know more about milieu, when we shall be able to perform this feat. The inner world of the organism holds a predestined element in the genome, in the chromosome garniture. It is predestined in as far as on the pattern of the genome the chances of the environment play. We know the most classical way in which Johannsen has derived the law of frequency and amount of variability as induced by the ambient world.[62] If A, B, C and D *etc.* are factors beneficial to the growth of an organ, let's say a leaf and a, b, c, d *etc.* factors harmful to such growth (sun or shade, rain or drought, cold or heat *etc.*), and these factors occurred in random combination we might expect, for 5 factors expectations which, when evaluated as +) for A, B, C, D and as -) for a, b, c, d to be the terms of the binomial $(1+1)^5$. If the number of factors be infinite, we obtain, as a limit, the probability curve,

$$y = \frac{N}{\sqrt{2\pi\sigma}} e^{-\frac{x2}{2\sigma 2}}$$

σ being the "mean error" or "standard deviation".

(See, however the extension given by Kapteyn, 1916).[63]

Now, is there outside the genome more to the "Innenwelt"? Is the ontogeny entirely predestined? Or is there another, innate, statistical variability independent of the milieu? This fact has never been tackled experimentally as far as the author is aware (Baas Becking, 1946b).[64]

Apart from the genetics, we have the factual milieu interne, which is a counterpart of environment, in as far as the organism has not created its own environment. In the warm blooded animal we meet with an organism in which the regulatory functions change in the outer environment! And not only may this milieu interne be kept constant. Man is, moreover, capable to create a fairly constant, artificial, outer environment. Umwelt und Innenwelt of man is one of the most interesting objects of study, but one of the most dangerous objects! For the student will be soon aware that man is trying to subdue the entire outer environment, and that a great imminent conflict lies at our door! However, most organisms do not cause this difficulty. Their regulatory functions are limited and they do not, for if they do, to a very limited extent regulate the outer environment. Barcroft may be very enthusiastic about a worm that digs a burrow and is able to live in it because of the wonderful properties of its haemoglobin, but this worm has not regulated its environment, it has become its counterpart, just as its tube is the mould of its body.[65] It is unable to alter it except, may be, for digging another burrow into it. For the rest it is a slave of its environment.

60 Jakob von Uexküll (1864-1944). Uexküll views organisms in terms of information processing. He argues every organism has an outer boundary, which defines an Umwelt. Rather than the general meaning, Uexküll's concept draws on the literal meaning of the German word, which is 'surround world', to define the Umwelt as the subjectively perceived surroundings about which information is available to an organism through its senses. This is a subjective *Weltanschauung*, or 'world view', and is therefore fundamentally different from the black box concept, which is derived from the objective Newtonian viewpoint.

61 Reference to Androcles pulling the thorn from a lion's paw. See for instance *Aelian on Animals* VII, 48.

62 Reference to Johannsen (1909). Danish plant scientist Wilhelm Ludwig Johannsen (1857-1927), a founding father of modern genetics. He coined the terms 'gene', 'genotype' and 'phenotype'. Johannsen's proposal that changes in heredity resulted from sudden mutations rather than from slow processes of natural selection was seen at the time as a threat to Darwinian theory, though later research showed otherwise. Johannsen's findings supported the hereditary theory of the Dutch professor Hugo de Vries. See Zevenhuizen (2008, p. 325-326 and p. 443-444).

63 The formula is the probability density of the normal distribution. The Groningen astronomer professor J.C. Kapteyn (1851-1922) demonstrated that in nature most distributions are asymmetric. In *Geobiology* 1953 Baas Becking remarked (p. 416-418):

> Kapteyn (1916) has shown that causes independent of the size of the individual variants leads to normal distribution curves, while those dependent on size produce skew curves. The latter appears to be the general case, as follows also from a consideration of growth. These considerations only apply when the external environment is dictatorial. Drion (1936) has pointed out that, apart from the hereditary make up, even vegetative offspring of the same mother plant will show a different reaction to external influences; the "constitution" of this offspring, once established in a certain susceptible period, will cause the variants to remain different for the rest of their lives. This, of course, simply refers the beginning of the milieu influences to a very early stage in development and does not invalidate the arguments given above.
>
> As a matter of fact, frequency distributions, while often approaching the normal, are very diverse (B.B. and Drion, 1936). The normal, or Gaussian error curve is used as a convenient reference. […] Without making a fetish out of this normal distribution it should be stated that these ideas are still in harmony with modern opinion on the relation between "nature" and "nurture". Nature (the genetically fixed complex of characteristics) represents the "individu idéal" and Nurture, the milieu extérieur, provides the variation on this theme. It will be seen that this concept, however, is insufficient to account for the more fundamental reaction of organisms to environmental influences. Neither the theory of limiting factors nor the invocation of probabilities accounts for another general characteristic of the milieu exterieur, the optimum relations.
>
> The milieu factor tends to slow down vital functions beyond a certain optimal value. In photosynthesis, for instance, supra-optimal light intensity, carbon dioxide tension or temperature will cause an exponential decrease in the rate of the assimilation. In infra-optimal or under optimal conditions, the exchanges between internal and external milieu may be harmonious, and they may lead to a temporary "stationary state", but under supra-optimal conditions a "drift" in this stationary state becomes increasingly noticeable. It is usual to conceive the optimum curve, expressing again the "yield" as a function of the intensity of a certain milieu factor, as the resultant of an ideal yield curve and of a line (usually exponential) expressing a decline due to a "brake action". These optimum relations are also the rule in enzymology when enzyme activity is plotted against pH or against temperature.

Kapteyn and Van Uven (1916) and Kapteyn (1916). See also Baas Becking and Drion (1935), and Drion (1936).

64 The reference is to Baas Becking (1946b), which he submitted to *Acta Biotheoretica* on February 5, 1944. The study was published in 1946. See for Baas Becking's position in the discussion about Nature conservation De Jong (2002, p. 156-170).

65 Reference to Joseph Barcroft (1872-1947), physiologist well known by his research of the function of haemoglobin in respiration. See also Section 5.10.5 for a reference to Barcroft and Barcroft (1924).

1.4 Holism

General J. Smuts, a keen biological observer, has written a remarkable treatise in which he announces the concept of holism.[66] Holism is no novel claim; it wants to understand "the organism as a whole", as an entity, as a thing perfect in itself. After what was said in the preceding section it will be clear that an organism "out of its environment" is no longer "the organism". This is not meant in a mystical way. No metaphysics is necessary to see the advantage of the holistic attitude. We shall see later, for example, that the entire living nature is connected, like a large texture, a large web. By this is meant not a blood relation, but a mutualistic exchange of substances, a sort of super-symbiosis (Section 7). This web of life is made up of nearly all of the known organisms. There are precious few that are able to live on, independently. But by the increasing recognition of this fact by the discovery of more nutrilites (organic substances necessary for the life of an organism and active in very small quantity),[67] we come to the inevitable conclusion that in biology we have been just spelling words, not yet making sentences and much less; making sentences that make sense! Of course, this material exchange appeals to the chemist, but it is only an exposition of the mutual dependences of the organisms, which orders much more than chemistry alone! *Umwelt*, when free may be a vast area, covering the milieu of a number of organisms. When we take organisms as an oak tree, or a cow, we are dealing, biologically, with classes of organisms, grouped in their mutual dependence, around *Bos Taurus* L. or *Quercus robur* L., but the web continues, it covers more than we yet understand. O, the holistic concept is better than the bare organisational concept, as we are able to isolate the complex from its greatest connections, and to which it is joined by many links!

1.5 Definition of Milieu[68]

In the beginning of this section, the word milieu has been used to designate environment. It might be well to analyse this matter somewhat further. *Milieu is the integration of the objective environmental factors.* The milieu of a certain organism is not thought as an instantaneous picture but as the integration of the environmental conditions during a definite homogeneous vital stage of the organism. Milieu differs from Uexküll's Umwelt in so far as the Umwelt contains, as already stated, unspecific elements. Redefinition of milieu, as given here, reminds one of Walther's definition of facies in Geology.[69] In Section 3 the concept will be further elaborated.

If the German school speaks of "Stoffwechsel", exchange of substances, it means exchange between the external milieu, called "monde ambiant" by Bernard (1878) and the internal milieu, the "milieu interne".[70] This milieu interne is the integration of all the influences emanating from the organism itself and dictated by its genetic plan. If we therefore consider the earth in its exchange, and its "Stoffwechsel", with the organisms, we shall find an expression of the "milieu externe", chiefly in the organism, an expression of the "milieu interne", chiefly in terrestrial changes. We might well say, therefore that, due to the biosphere, the earth has its own metabolism.

In brines just the biological factor has been sorely underestimated. We must apply caution not to overestimate these factors, however. At various places in this essay, we shall meet with instances where it appeared possible to select between a chemical and a biological agent, as the cause of a certain phenomenon. This treatise will deal chiefly with the relation of organisms with the external milieu. Only at a few places relations between internal and external environment shall be further analysed. It will be seen that the earth often does not provide the milieu optimal for a certain organism.

1.6 Statement of the Problem

There is a contrast between biology and the other sciences. Mathematics, since it soared away from Euclid, is, in a way, extraterrestrial. Physics has left the earth to become astrophysics; the chemistry of the distant universe becomes increasingly known. The geologist, even, considers the morphology and the lithology of the moon. Biology, however, is still earthbound. It seems at present, sterile to consider a non-Ptolomeo biology, a Copernican biology so to say, where we cannot observe other celestial bodies accurately enough to even indulge in speculation.[71]

66 Jan Christiaan Smuts (1870-1950) South African statesman, military leader and philosopher. While in academia, Smuts pioneered the concept of holism, which he defined as "the fundamental factor operative towards the creation of wholes in the universe". In his 1926 book, *Holism and Evolution*, Smuts' formulation of holism has been linked with his political-military activity, especially his aspiration to create a league of nations. According to his biographer:

> It had very much in common with his philosophy of life as subsequently developed and embodied in his *Holism and Evolution.* Small units must develop into bigger wholes, and they in their turn again must grow into larger and ever larger structures without cessation. Advancement lay along that path. Thus, the unification of the four provinces in the Union of South Africa, the idea of the British Commonwealth of Nations, and, finally, the great whole resulting from the combination of the peoples of the earth in a great league of nations were but a logical progression consistent with his philosophical tenets.

See also Crafford (1943).

67 Baas Becking discussed the role of ergones and nutrilites in detail in Section 7.2. Nutrilite is used to designate a minimum substance, in contrast to nutrient. Anton Quispel (1943, 1946, p. 416) described 'nutrilite' as 'accessory growth factors'. Baas Becking was the supervisor of Anton Quispel (1917-2008) in Leiden. Because the Leiden University was closed during WWII, Quispel defended his PhD thesis in Groningen. Quispel was professor of Experimental Botany University of Leiden (1960-1983).
Nutrilite is also a brand of mineral, vitamin, and dietary supplements developed in 1934 by Carl F. Rehnborg.

68 In the introduction to Chapter III in his 1953 version of *Geobiology*, Baas Becking defined milieu (p. 164):

> The counter mould of life, the sum total or rather, the integration of environmental factors, we will call the "milieu". This concept, as originally used by Claude Bernard in his "Leçons sur les phénomènes de la vie" (1878) defined moreover, a "milieu extérieur" (or "milieu ambiant") and the "milieu interne", life consisting of a constant interplay between the two (Bernard, 1854).

69 Johannes Walther (1860-1937) defined the Law of facies in 1894:

> The various deposits of the same facies area and similarly the sum of rocks of different facies areas are formed beside each other in space, though in a cross section we see them lying on the top of each other. As with biotypes, it is a basic statement of far reaching significance that only those facies and facies areas can be superimposed primarily which can be observed beside each at the present time.

See López (2005).

70 See for Claude Bernard also above and Section 1.1.
See for the development of Claude Bernard's concept of *Milieu Intérieur*, F.L. Holmes (1986), C. Bernard, The *Milieu Intérieur*, and Regulatory Physiology. *History and Philosophy of the Life Sciences* 8, p. 3-25.

71 For Baas Becking 'Ptolomeic' stands for 'anthropocentric'. In his Inaugural lecture at Utrecht University on October 3, 1927, he made the observation:

> Every Ptolomeic system sooner or later finds a Copernicus, each Newton is followed by an Einstein. It has already been said so aptly by Eddington: "We have found a strange foot print on the shores of the unknown. We have devised profound theories, one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the foot print. And lo! It's our own".

See also *Ptolomeic or terrestrial outlook of biology* in the introduction of this transcript of *Geobiology*.

There are two moments however, that strengthen our forces in the existence of a non-terrestrial biology. In the first place, where subatomic, atomic, as well as molecular states of matter seem to be inevitably connected with external circumstances, the living state of matter may be, under suitable environmental conditions, equally inevitable. This consideration, which is wholly intuitional, needs not interfere with the problem of the *generatio spontanea*, as it presupposes only a cosmic (or at least interplanetary) transport of spores or cysts, as already stipulated by Svante Arrhenius.[72] The second thought, which encourages us to consider a non-Ptolomeo biology, is the fact that the extension of our science may be approached experimentally. Astrophysics, for example, is partly a laboratory science. If we knew more about planet's chemical conditions on, let us say, the surface of Jupiter, where, according to Russell, ammonia and methane are paramount in the atmosphere and in hydrosphere, it should be possible to perform experiments in liquid ammonia at a suitable temperature.

Leaving further speculation aside, it seems useful, however, to remember that most probably terrestrial biology is only one mode of life; one "phenomenal" side of an environment science, which we only perceive in part. Radiation and gravity are the determining forces of the type; the mode of the terrestrial biology and, of the two, radiation is the most important. Gravity determines the distribution of the elements in and on the earth - the composition of the lithosphere, hydrosphere and atmosphere. Radiation determines, under more, its temperature. This temperature, average ±15 °C (278.2 °K) is situated within the range of liquid water. The biosphere coincides with the region in which water, is, at least in certain seasons, in the liquid state. Our biology is a water biology and living things contain so much water that much science that appeared as biology, only proved to be a description of the properties of this very universal compound. Where Goethe said, "Blut ist ein sehr besonder Saft",[73] it should be countered by what Ant. St. Exupéry exclaimes in his *Terre des Hommes*, "Eau, tu n'as ni goût, ni couleur, tu n'es pas seulement nécessaire à la vie, tu es la vie".[74]

The biosphere covers the earth as an extremely thin green film. It is of water and of sunlight made, it is bathed in a solution of the lithosphere (the hydrosphere) and it is profoundly influenced by it. It inhales the atmosphere. But its relations are mutual; there is give and take. This thin green film influences the earth, its chemical composition as well as its physical properties. It influences the earth more than its disproportionally small content should lead us to expect. There exists therefore, a close relation between living things and the earth, a mutual relation. This relation we shall call geobiology. Quite recently in geological history, one organism has arisen, an organism with power to change the face of the earth. Man, who claims the earth as his own, by divine right (*Genesis* 1, 30), has initiated a geobiological epoch, which may be called the *anthropic* epoch. Man is, geobiologically, one of the most important agents and his influence deserves special treatment. The influence of other organisms has been chronically underestimated. Until recently, there has been a tendency to delegate geochemical phenomenon to chemistry. Even the genesis of petroleum has been viewed from this point of view. This should not amaze us when we see that the concept of geobiology required, and presupposed, the development of a vast body of sciences such as geomorphology, mineralogy, plant physiology, general bacteriology, *etc*. Sciences that, moreover seemed, at the onset, unrelated and hardly even mastered by a single person. In this anthropic phase of our science, moreover, economics and sociology sneak in as well. They touch the so called Humaniores, realms of human endeavour infested with emotionalism, dogma and preconception. At the onset therefore, our task seems rather hopeless. The strength of science, as G.N. Lewis has aptly said, lies in its naivité,[75] and if we, ignoring all the future obstacles which shall later hamper our progress, simply start on a simple task of organising what we have been able from our own and from extraneous experience, we have done all that may be expected from us. For every specialist that reads this book, there will appear a vast lacuna. But it seemed, particularly in these days, when man seems driven to destroy most of the remaining biosphere, not without its use to make

72 Svante Arrhenius (1859-1927), Swedish scientist, Nobel Prize for Chemistry 1903. The reference is to *Das Werden der Welt*, Leipzig (1908). Baas Becking referred to the 'panspermia concept' that was explored in the nineteenth century by the physicist H.E. Richter, who first recognised that meteorites contain carbon and then supposed that meteorites could have brought the first life to earth. The panspermia concept was promoted by Lord Kelvin. At the end of the nineteenth century this idea was popular in science and in the twentieth century its main promulgator was Svante Arrhenius. In his Inaugural Address in Utrecht, Baas Becking (1927) showed himself critically attracted to the panspermia concept:

> […] when we do not want to see life as the sum of an infinite number of coincidences, culminating in a great improbability, if life is a true new category, a true high rise form of organisation of the substance, yes, then we have to think of life as a cosmic phenomenon. We are here in the illustrious, yet somewhat dangerous company of Svante Arrhenius, who thinks life has cosmic dimensions, as before him Helmholtz and Kelvin did and those who think life to be eternal as Richter, who does not assume that the germs of life come from the moon, as Cyrano de Bergerac and Sales Guyon de Montlivault believed, but from the great world space, directed by the pressure of light, gripped by other forces, until the atmosphere in its turmoil carries the germs to the earth crust.
>
> In the interplanetary space the organism undergoes, not protected by an atmosphere, the full effect of the ultraviolet light. On this basis, Becquerel calls Arrhenius's theory untenable. However, as Molisch points out, and I can only confirm this, Becquerel has not made a representative choice in the organisms used for his tests. And perhaps the organisms that endure the growing desert sun, the purple bacteria, are able to tolerate interplanetary transport successfully. Pure hypothesis you will say. We study the earthly life in practice. Surely, we will never be able to study another life? These objections occurred in myself after reading Arrhenius's fascinating book "*Das Werden des Welts*". What does it give, I thought, if Molisch says: "... und von vornherein ist es eigentlich doch höchst unwahrscheinlich, dasz gerade nur unsere Erde dieser kleine Punkt im Kosmos, Lebewesen tragen sollte ..." [and from the outset it is actually highly improbable that just our earth, this small point in the cosmos, should carry living beings ..], we will never make this improbability into a certitude or impossibility.

Reference to François de Sales Guyon de Montlivault (1765-1846) who published in 1821, *Essai de Cosmologie, ou Mémoire sur la Cause et la Nature des Mouvemens Célestes; sur la Cause et la Nature de la Lumière*. He was one of the first proponents who suggested that earth life had been seeded from the moon. Further reference to Molisch (1912, p. 42).

In the 1953 manuscript of *Geobiology* (p. 92) Baas Becking referred again to Arrhenius who:

> […] wanted spores and cysts to embark upon interplanetary trips, carried by radiation pressure. We know now that the cruel, undamped ultraviolet radiation would burn every organism to bits as soon as it left the protective atmosphere. Even larger molecules would not stand this radiation without being disintegrated. Moreover, Arrhenius's theory expresses itself only on the *transport* and not on the *origin* of the living structure.

73 Goethe *Faust*: "Blut is ein ganz besonderer Saft" [Blood is a very special juice].

74 Baas Becking gave his own version of the original expression: "Eau, tu n'as ni goût, ni couleur, ni arôme, on ne peut pas te définir, on te goûte, sans te connaître. Tu n'es pas nécessaire à la vie, tu es la vie." [Water, you have no taste, no colour, no aroma, you cannot be defined, you are tasted, without knowing you. You are not necessary for life, you are life.] *Terre des Hommes* (1939) Antoine de Saint-Exupéry.

75 Reference to G.N. Lewis (1925), Ultimate Rational Units. *Philosophical Magazine* 49, p. 750:

> [For] the prediction of an unknown relation between physical quantities, the common method of dimensional analysis has no logical; or mathematical basis. If we employ it in the hope that it may lead to useful results, this hope must be based not upon any established principles of science, but upon some vague belief in the simplicity of nature.

Gilbert Newton Lewis (1875-1946), American physical chemist. Dean of College of Chemistry University of California, Berkeley. During his Stanford years Baas Becking probably was acquainted with Lewis.

See also H.R. Post (1960), Simplicity in Scientific Theories. *The British Journal for Philosophy of Science* 11, p. 32-41.

an attempt to formulate the skeleton of a geobiology, even if the result be incomplete, erroneous and biased. Maybe the book is not written for a specialist but for those who are curious to link their laboratory experiences to the manifold imagery of the field work. For those who consider, with Sergei Winogradsky,[76] the pre-culture bacterium more or less as a lion in a zoo. Maybe there are such that, after a lifetime of laboratory work, feel a certain nostalgia for their old hounds in the field.

G.Th. Fechner in his [*Vergleichende*] *Anatomie der Engelen* (1854?) [= 1825] actually describes our planet if it were living, if it had its own metabolism.[77] This metabolism of the earth is partly geological and partly biological. There are chemical reactions in the newly extruding magma, there are radioactive processes, but also there is the influence of the living surface film of the earth upon the composition of the atmosphere, upon calcite deposition, upon sulphate reduction, upon formation of crust-biolithic. Geobiology goes further than the metabolism than the "Stoffwechsel" of the earth crust. It also deals with the "Formwechsel", the geomorphological influences of the living beings. Orogenesis is the process geophysical and geochemical, but reef formation is a biological process. The clay soil on which we live in Holland, a subfossil excrement, in a sense a coprolite of the heart-shell and the mussel. Chemical as well as morphological processes come into play and apart from these there is a physical influence of the organism, on thermal equilibria in the atmosphere. For instance, that creates another category.

1.6.1 Cyclic processes

In geochemistry it is convenient to think of most processes as cyclic. So, oxidation and reduction connect an element M, its highest oxide M_xO_4 and its hydroxide MH_2. There will be energy required for the reduction, liberated as oxidation, there will be exchange of electrons, there will be travels of the element in the lithosphere and hydrosphere, the atmosphere and the biosphere. These happenings are recurrent. The show is continuous and all acts are enacted simultaneously!

1.6.2 Disturbances of the cycle

A cycle, in a way represents a departure from a stationary state only in that there is a "shift" in the equilibrium, which is recurrent. If the recommence in this shift is incomplete, our phase in the cycle will become exhausted, one product will accumulate, like a factory artefact, manufactured on one endless belt. This may be due to a difference in velocity between the various links in the chain process. The acid medium, for instance, certain bacterial processes may be slowed down, here we may get accumulation of organic material that would not occur in alkaline medium. In this way, through a disturbed cycle, we may explain most biogenic accumulations in nature. Our oil, coal, and great deposits, saltpetre, guano and, to a certain extent, brine are all to be considered as "slugs" in the cycle of the carbon. Role of organisms (coal, oil, brine deposits).[78]

1.6.3 Contents of this book

This book deals with the organism and the earth. It will endeavour in a short scope, to describe the earth as an abode for life, the physical, the chemical and the biological factors of the milieu. Then it will deal with living matter in its longer aspect as far as distribution and metabolism is concerned. The third part deals with the influence of the environment upon the organism, and the relation of the organisms to a laboratory environment. The fourth part treats the influence of the organisms upon the atmosphere, the hydrosphere and upon the lithosphere. After that the mutual relation of organisms shall be described. Man, as maker of milieu, deserves a separate section. A few theses appear in this book, which ask for a separate amplification before starting. They are simple and obvious, yet they seem forgotten.

a. ***"Nothing in the world is single"***,[79] is more than a line written by a poet in love, it does not pertain to that form of symbiosis which we may call "gamosymbiosis" alone.[80] Even the independent, autotrophic higher plants are, in their flower biology, connected with insects, in their host biology with fungi. Not only the classical cases of symbiosis, but nearly all synecological questions stipulate the dictum used by P.B. Shelley. In the accompanying figure some relations between six organisms are depicted. The relations vary from true symbiosis to parasitism and the food relation. Even within a multicellular organism, the individual cells and tissues live in mutual relation. Life, therefore, is a complicated web, spread over the earth. A magic web, of which not a single strand may exist without its own, elaborated strands (Fig. 1.1).

Geobiologically this thesis, which will be elaborated in Section 7, is of the utmost importance. It is, in the first place, hard to indicate a certain organism as the agent of a specific geochemical reaction. We have to know the whole complex of organisms centring around that particular point in the web of life. Furthermore, most of the relations indicated above are material relations. There is continuous exchange or rather interchange of chemical substances between organisms. This interchange is, of course, part of the "terrestrial metabolism", and the shape of the milieu has to be the common denominator of the environments of all of the organisms, which cover this part of the web.

b. ***"Everything is everywhere".***

c. ***"The milieu selects"*** (Baas Becking, *Geobiologie,* 1934).[81]

The founder of general microbiology, M.W. Beijerinck, has intuitively employed both principles, which are expressed above. In his masterly lecture for the Royal Academy of

76 Sergei Winogradsky (1856-1953). His research on nitrifying bacteria would report the first known form of chemoautotrophy, showing how a lithotroph fixes carbon dioxide (CO_2) to make organic compounds.

77 Gustav Theodor Fechner (1801-1887), *Vergleichende Anatomie der Engel* (1825) [Comparative Anatomy of Angels], a parody written under the pseudonym of "Dr Mises." Fechner describes the heavenly shaped angels in positive contrast with the faulty shaped men on earth.

78 Don E. Canfield in his annotation of the English version *Geobiology* (2016, p 67-68 and 70) observed that Baas Becking by "differentiating between the fast cycles of biological turnover and the slower cycles of geological turnover […] understood, at least in general terms, how biological cycles and geological cycles transferred elements between them".

79 Percy Bysshe Shelley, *Love's Philosophy* (1819): "Nothing in the world is single, All things by a law divine, In one spirit meet and mingle-Why not I with thine?"

80 See for gamosymbiosis Section 7.7.3.

81 Baas Becking (1931b), *Gaia or Life and Earth*, p. 8:

> The cosmopolitan occurrence of lower organisms, which gives us the basis for the study of external conditions, is curious enough to be elevated in ecology to a rule, to a law, to "the law of Beijerinck". A law that says "everything is everywhere". Everything is everywhere, and the milieu selects. The more extreme the milieu, the sharper the selection.

In his Utrecht University Inaugural Address (Baas Becking, 1927) he already concluded:

> Life is eternal, there is potential everywhere, the milieu selects, determines the form. The earth's general standard is only a particular case. And this, my listener, is what I understand among the generality of life.

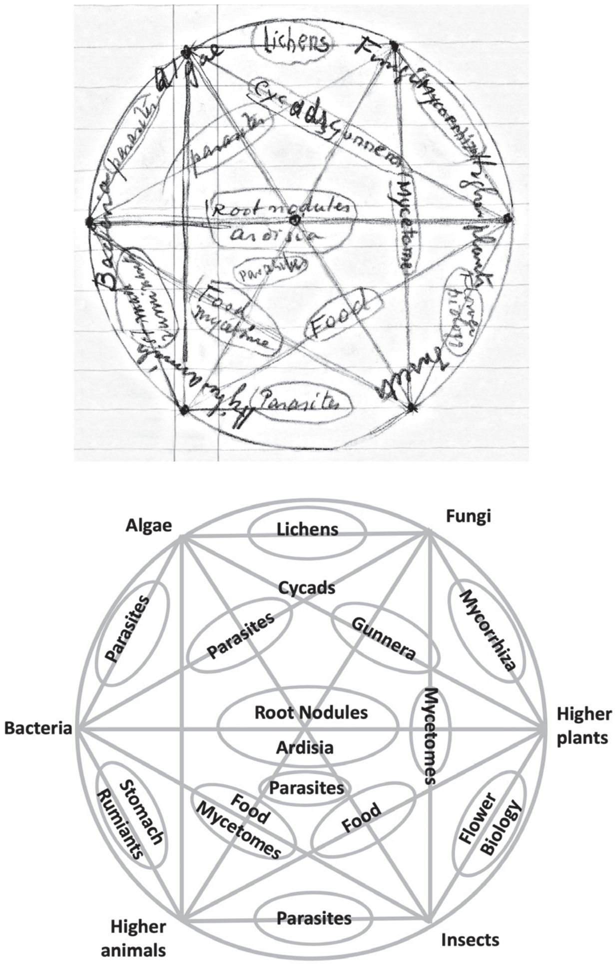


Figure 1.1 Relation between fungae, algae, bacteria, insects, higher animals and higher plants.

Sciences in 1913 he has outlined a method of approach of microbiology, which is founded on the fact that if one prepares a specific nutrient medium and maintains this medium under specific conditions, any infection material will yield an identical organism.[82] So, Van Niel isolated in 1929 purple sulphur bacteria from almost any infection material by keeping pH, H_2S pressure and mineral composition specific, while illuminating his cultures.[83] Specific instances of the method are given in Section 3.1 of this treatise. The section on distribution will give the experimental indication that most microbes are cosmopolitan, and that, therefore the "milieu-laws" apply.

In the schematic representation, given below (Fig. 1.2), the organism, whose milieu is described by field A lives in freshwater, aerobically, in the dark. This is not a very specific milieu. Organism B however, lives anaerobically in the light in a salt solution. It is most probably a bluegreen alga or a *Euglenoid*, as these are the only photosynthesis capable of living anaerobically in brines. By preparing such milieu conditions one of the two last named would be the answer! The organism *resonates* with the milieu. The above theses have met some opposition. The criticisms of Dr. J. Heimans shall be dealt with in this essay.[84]

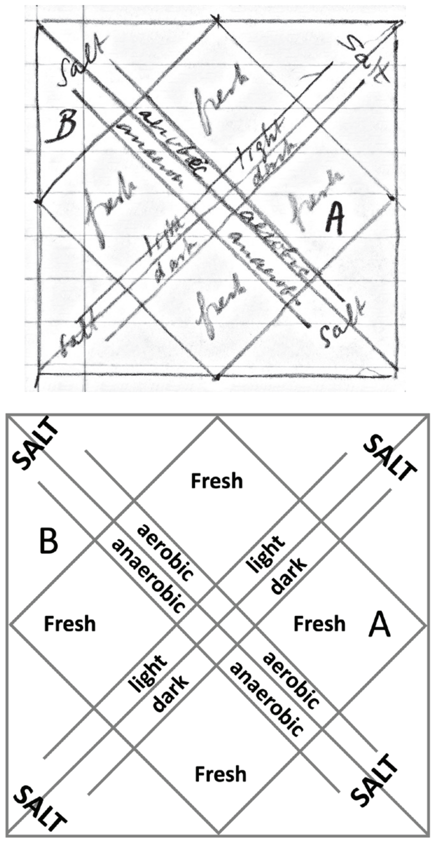


Figure 1.2 Compartmentation of aquatic milieu that are fresh or salt, aerobic or anaerobic, light or dark. Organism A is aerobic, lives in freshwater in the dark, organism B is anaerobic, lives in salt water in the light.

82 Baas Becking referred to Beijerinck (1913).

83 Reference to Cornelis Bernardus van Niel (1897-1985), Dutch-American microbiologist. In 1927 Baas Becking offered him an appointment as associate professor in the new Jacques Loeb Laboratory at the Hopkins Marine Station on Monterey Peninsula where he was the director. In 1931 Van Niel published with F.M. Muller, *On the Purple Bacteria and their Significance for the Study of Photosynthesis*. In 1932 Van Niel published, *On the Morphology and Physiology of the Purple and Green Sulphur Bacteria*. In these publications he was the first scientist to demonstrate that photosynthesis is a light dependent redox reaction in which hydrogen from an oxidisable compound reduces carbon dioxide to cellular materials.
In *Geobiology* (1953, p. 241), Baas Becking referred to:

> The brilliant work, both in the experimental and in the theoretical field by C.B. van Niel, started in 1929, has not only clarified the nature of the primary photosynthetic reaction, but also shown that the role of water in this process is both an important and curious one.
> The general equation for photosynthesis would be:
> $CO_2 + 2H_2A = (CHOH) + H_2O + 2A$
> (CHOH) indicating a substance "of carbohydrate nature".

See for C.B. van Niel, *Preface*, Section *Herzstein Professor and Director Jacques Loeb Laboratory* and also Section 4.6, *Photosynthonts*.

84 Reference to Jacobus Heimans (1889-1978), botanist and nature conservationist. He was the son of Eli Heimans (1861-1914), well known nature conservationist and propagandist and together with Jac. P. Thijsse (1865-1945), founder of *De Levende Natuur*. As a student Jacobus Heimans was assistant of Hugo de Vries. After WWII he became Professor of Botany and Genetics.
The reference to 'criticisms' was not identified. Baas Becking probably referred to Heimans', PhD thesis (1935) about the dispersal of *Desmidiaceae* (supervisor Th.J. Stomps). See also Heimans (1937), *De transportfactor in de plantengeographie*. Also, it is possible that Baas Becking referred to Heimans objections against the Braun-Blanquet 'flora' (see Section 1.2.1.a and b). In this manuscript and in the 1953 updated version of *Geobiology*, Baas Becking did not refer to the criticisms of Jacobus Heimans.

2. THE EARTH

2.1 Origin and Development

2.1.1 Introduction

Astronomists and geologists agree that this universe suffered a great conflagration about 2,000,000,000,0000 years (two thousand million years) ago. Umbgrove (1942) has dealt with these and called allied matter in his book *The Pulse of Earth*.[1] Our planetary system seems to have originated in this epoch and, according to all probability, the earth, together with the other planets, was torn from the sun. It must have had a very high temperature at the time of birth. It is probable, but still uncertain, whether the moon was torn off from the still plastic earth.

2.1.2 Sial and sima crust and regulus hydrogen hypothesis[2]

Studies of meteorites have taught us that the abnormally high specific gravity of the earth (5-6) is probably caused by the nature of the core, which should be a nickel-iron alloy (according to some it might be highly compressed by hydrogen!). Now from the propagation of earthquake waves we know that there seems to be a discontinuity at about 3,000 km depth. There is another at a depth of 1,200 km. Now Goldschmidt (1922) assumes that during the cooling of the incandescent earth, an enormous metallurgical process took place, in such a fashion that the regulus, the heaviest core, attained the deepest position, this surrounded by the 'stoma' a region called chalcosphere, containing sulphides and oxides, further surrounded by the 'slug', called eclogite.[3] The outer 120 km or so is the light silicate mantle (for densities see Fig. 2.1). The most precious substances, the heavy metals, only occur occasionally in the outer shell. In this silicate mantle the lighter Al silicate (sial) float apart upon the heavier magnesium silicates (sima). There was, therefore, first a separation by gravity; according to Goldschmidt items of similar radius could take each others place in a crystal lattice. This accounts for the recurrence of many substances in minerals.

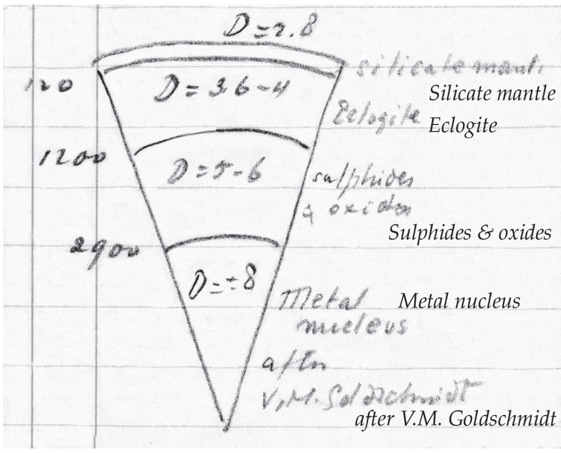


Figure 2.1 Schematic cross section of the earth. Transcript of legend: Silicate mantle (D[ensity] 2.8), Eclogite (120 km, D = 3.6 – 4), Sulphides and oxides (1,200 km, D = 5-6), Metal nucleus (2,900 km, D = ± 8). After V.M. Goldschmidt (1922).

2.1.3 Weathering

Most of the oxygen was used up in the formation of oxides. If the core had been exposed only a small amount of its sima could have been oxidised, as even all of the oxygen present would not have sufficed! So, the earth outer crust is chiefly oxide, it dictates the composition of the lithosphere. The original atmosphere has no oxygen, the hydrogen, while abundant was slowly but surely removed from the atmosphere, as the gravitational field is too weak to hold it. Lighter gases left the earth, only those in the neighbourhood of M.W. [Molecular Weight] 14-18 (nitrogen, oxygen, water vapour) being permanently fixed. Much later, when the earth' crust was permanently fixed, water vapour began to condense.

2.1.4 Geomorphology

The partition between land and water as we know it now, is probably very old. The theory of continental drift, proposed by Wegener, has been largely abandoned by now. Orogenic period, glacial period and epochs of increased volcanism occurred rhythmically (see Umbgrove, 1942, *The Pulse of the Earth*). Geobiologically important is the hypothesis of Holmes,[4] according to which the level of the ocean over the entire surface has risen ±40 m since the last glacial epoch. North Sea, Java Sea and many other shallow seas originated

1 Reference to the Umbgrove (1942). Johannes Herman Frederik Umbgrove (1899-1954), Dutch geologist and Professor in Historical Geology and Palaeontology Technical University Delft.
In the 1953 version of *Geobiology* (Baas Becking, 1953a), Baas Becking remarked (p. 159-160) about Umbgrove's *The Pulse of the Earth*:
> Mountain formation, transgression of the oceans, formation of basins as well as the climate show rhythmical changes, called by Umbgrove "the Pulse of the Earth". The frequency of these pulses is about 40-45 million years, while there is a much longer periodicity, of about 250 million years of intense glaciation. While the formation of the larger groups of both vertebrates and higher plants was completed in the Carboniferous, renewed explosion of speciation started at the end of the Cretaceous, involving mammals, birds, insects and flowering plants. Here again we are in a period of glaciations. It would be tempting to suppose that an early "wave" of speciation, in the early Cambrian or late Precambrian, originated also in a glaciation period. Evolution has not been a steady stream; it has apparently been speeded up at intervals, and it seems logical to connect these changes with the geological cycle.

2 The small drawing is a copy of Abbildung 3 in *Die Eruptivgesteine* by Barth (1939, p 14). Baas Becking had a copy of the book in the Utrecht prison. Thomas Frederik Weiby Barth (1899-1971), Norwegian mineralogist. V.M. Goldschmidt was one of his teachers.

3 According to Goldschmidt (1922):
> It is conceivable that the original state of the Earth was a homogenous or nearly homogeneous mixture of the chemical elements and their compounds. Today, however, the Earth is far removed from a homogeneous state. The material distribution within the Earth has by no means reached a final equilibrium state; we observe instead an active redistribution of matter and energy. The processes, which have resulted in the inhomogeneity of our planet and still contribute to the migration of material I would summarise in the expression "The Differentiation of the Earth".

Goldschmidt established the basis for the new geochemistry and pointed out the importance of the primary geochemical differentiation of the elements during geological evolution. He classified the elements in the earth into four groups: siderophile, chalcophile, lithophile, and atmophile. These are groups such that the elements have an affinity for metallic iron, for sulphide, for silicate, or for the atmosphere, respectively. Later he added biophile, for those elements commonly concentrated in organisms. The geochemical character of the element is determined to a large extent by its electronic configuration, and thus related to its position in the periodic table. It was during this period of study that Goldschmidt showed the significance to geochemistry of meteorite compositions. Astronomical and chemical evidence, point to the fact that the earth and meteorites have a common origin.

4 Reference to Arthur Holmes (1890-1965), British geologist.

since the last glaciation by melting ice. Of undisturbed rock there is very little on the continents. On the ocean bottom, according to Escher, the sima is coming to the surface.

2.1.5 Summary

We live on the cover of a great crucible of which the valuable core cannot be reached. Only traces of heavy metal contents penetrate into this outer shell. The gravitational differentiation and affinity for oxygen have made these things to pass. The nitrogen has almost quantitatively passed into the atmosphere, which is a shell of gas as much as the gravitational field of the earth will hold. The hydrogen escapes; CO_2 and oxygen are better represented on the lower atmosphere. Therefore, only a thin shell is habitable.

2.2 Present status, geophysical[5]

2.2.1 Isostacy

The earth is not a perfect sphere, but according to the ideas already developed by Laplace, flattened at the poles, a so called geoid. Apart from the difference in the acceleration of gravitation going from the pole to the equator, we find local disturbances in gravity. These may be due to penetrations of heavy material or, to printing in of lighter material. Movements on the earth's crust tend to equalise these masses in order to equalise the forces. This is the principle of isostacy. Due to the difference in specific gravity of sima and sial, the deviations in gravity may vary. Over the oceans there is usually a deficiency, over the continents an excess. Isostacy also requires heavier material under the oceans. Here the sima comes to the surface (B.G. Escher).[6] The ocean floor is, therefore, lithologically different from the continents. This has little bearing upon our problem, however, as the biotic condition at abysmal depth is derived from the same superficial strata.

2.2.2 The work of Vening Meinisz[7]

Vening Meinisz has measured the acceleration of gravity by means of a pendulum aboard a submarine over several oceanic tracts, particularly near the Dutch East Indies. His results combined with those of recent oceanographic expeditions (Snellius, Meteor), warrant the conclusion that excesses and deficiencies in gravity go hand in hand with zones of maximal seismic and volcanic disturbances. To account for these deviations a buckling of the sial has been assumed. This has been made probable by the beautiful experimental work of Ph. Kuenen.[8] This downfolding and wrinkling (so to say) has determined the face of the earth crust (Fig. 2.2). Orogenesis has been performed this way (Umbgrove, *The Pulse of the Earth*) and subsequent weathering has brought down the mountains to their present level. We have, therefore, a geoid with variation from sea level of ±10 kilometres. This determines the "stage of the life drama", with its variation from $^1/_{10}$ to 1000 atmospheres pressure, with oxygen pressures varying from $^1/_5$ to zero.[9]

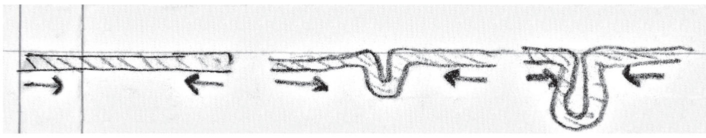


Figure 2.2 Downfolding and wrinkling of the earth crust.

2.2.3 Wegener's theory[10]

According to Alfred Wegener the continents, which were originally joined have, when the earth' crust became stabilised, began to wander and to draw apart. South America fits snugly into the "armpit" of Africa, even a lithological continuity could be found here (J. Dutoit).[11] So N. America has drifted from Europe. The pole also, has shifted its position materially so, that, climatologically, the occurrence of *Ginkgo* and other fossils from moderate climates could be accounted for. This very ingenious hypothesis has influenced biology, and in particular biogeography, considerably, although on closer inspection, it does not seem to account for the facts. Several tertiary florae of moderate character occur over the same ground circle of latitude, showing that the pole has kept about its position. Also, the wandering continents seem, in view of recent geological work, increasingly improbable.

2.2.4 Insolation and oceanic currents

Oceanic currents originate through differences in temperature and salinity, or of the density of the water. The origin of the one well known current, the so called Gulf Stream, is given below. Polar ice causes a vertical water movement downwards; tropical insolation causes a vertical movement upwards. These two vertical movements are closed into a circuit - superficial water flowing towards and abyssal water away from the pole (Fig. 2.3).

5 The following sections are based on the work of F.A. Vening Meinisz. Between 1923 and 1929 he embarked in small submarines for some uncomfortable expeditions. His goal was to establish the exact shape of the geoid and the Earth. The vast amounts of data that his expeditions yielded were analysed and discussed together with other leading Dutch earth scientists of the time, J.H.F. Umbgrove, B.G. Escher and Ph.H. Kuenen.

6 Berend George Escher (1885-1967), Dutch geologist, Professor of Geology in Leiden University since 1922. Baas Becking referred to his contribution to the discussion on zones of negative anomality's: *On the Relation Between the Volcanic Activity in the Netherlands East Indies and the Belt of Negative Gravity Anomalies Discovered by Vening Meinesz* (1933).

7 The Dutch geophysicist Felix Andries Vening Meinesz (1887-1966), known for his invention of a precise method for measuring gravity. Thanks to his invention, it became possible to measure gravity at sea, which led him to the discovery of gravity anomalies above the ocean floor. He later attributed these anomalities to continental drift. See Section *Wegener's theory.*

8 Philip Henry Kuenen (1902-1976), Dutch geologist, Professor of Geology, Groningen University (1946-1972). Baas Becking referred to *Geological Interpretations of the Bathymetrical Results* (Snellius Expedition, vol. 5, part I) published in 1935. This was the result of his participation in the Snellius expedition (1929-1930).

9 The reference to "stage of the life drama" is to Lotka (1924), *Physical Biology*. Alfred James Lotka (1880-1949) American mathematician, physical chemist and statistician. According to the Introduction to the 1953 version of *Geobiology* (Baas Becking, 1953a, p. 6-7) Baas Becking was greatly indebted to Lotka's *Physical Biology*, which he considered as "a great and continuous source of inspiration".

> It is not only a treasure house of facts, it gives a complete system of geobiology, a system as yet but imperfectly explored. Only parts of Lotka's magisterial treatment of the relation between organisms and environment have found resonance in later literature and these are almost exclusively concerned with the statistics of populations. […] Lotka acknowledges his indebtedness to the great physiologist Claude Bernard, a scientist who also dared to venture beyond the limits of his own specialisation and to whom we owe the modern concept of 'milieu' […] The Geochemical development is chiefly due to the work of V.M. Goldschmidt (*Grundlagen der quantitativen Geochemie*, 1933), preceded by that of W. Vernadsky (*La Géochimie*, 1924).

For Lotka's "stage of the life drama", see also Section 4.1.

10 Reference to Alfred Lothar Wegener (1880-1930), German polar researcher, originator of the theory of Continental Drift. His hypothesis was controversial, but nowadays a substantial basis for the model of plate tectonics. According to Sapp (1990, p. 305), the attacks against Wegener and his unified theory, between the two world wars, occurred against a background of anti-German hostility.

11 Reference to Alexander L. Du Toit (1878-1948), South African geologist, promotor of Alfred Wegener's theory of Continental Drift. Baas Becking referred to Du Toit's, *Our Wandering Continents* (1937).

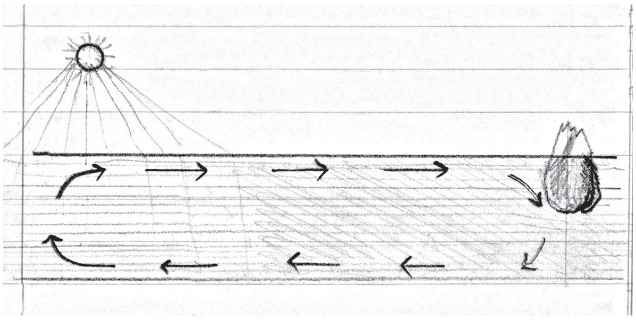


Figure 2.3 Vertical and horizontal water currents from the pole to the tropics and back.

Geobiologically ocean currents are important for:

1) Vertical currents change the condition of Colby;[12]
2) They often bring fresh minimum elements;
3) Horizontal currents are important vehicles (katadromic and anadromic fish, eels, Joh. Schmidt);[13]
4) The influence of a warm or cold superficial stream influences climate profoundly, as in Europe, or the cold Japan stream in California.

2.2.5 Winds

Temperature, gradients and rotational velocity of the earth are the prime causes of the currents (Fig. 2.4). The high altitude current from equator to pole is akin to the heat expenditure oceanic current. The stratosphere winds heading W-E is caused by the earth rotation. From W. Humphreys' book *Physics of the Air* brief statements should be taken as to the origin of the principal winds.[14] Monsoons are caused by insolation of land masses and the rising air engendered thereby. Troposphere winds are geobiologically the most important. They act as distributors of latent life, they also, together with oceanic currents, determine climate. The vertical air currents may carry up objects to such a level that they reach the rotational circuit and are thus transported once or several times around the earth before they settle (see Section 4.2). Winds have a great influence upon evaporation; also, the height of a tree is not determined by the properties of water, but by the average wind velocity (wind velocity may be as high as 200 mm/sec).

See further Section 4.3, *Distribution, Cosmopolitans, Physical Causes*. Fig. 22 'Verbreitung des Aschenfalls des Katmai' from Barth (1939, their Fig. 4.11a).

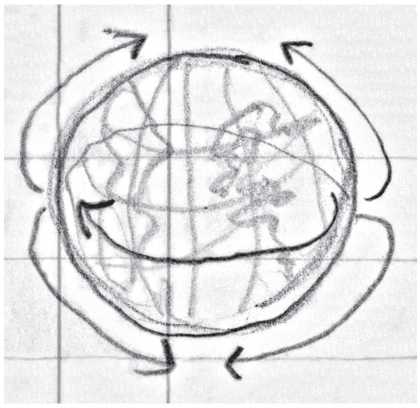


Figure 2.4 Wind currents related to temperature gradients and rotational velocity of the earth.

2.2.6 Temperature

The earth radiates as a black body of ±288 °K. Temperature may vary, at the surface, from ±80 °C on black, insolated rock, to -60 °C near the cold pole of Verkhoyansk, Siberia.[15] On the pole the Antarctic is colder than the Arctic, because the earth is in aphelion during the Antarctic winter. The earth keeps its surface temperature because of its atmosphere, which efficiently blankets the entrapped solar heat. Celestial bodies without atmosphere like the moon, show extreme (+150 to –100 °C) diurnal temperature variation, which makes them misfit as an abode of life. The earth temperature is further regulated by the physical properties of water. The high specific heat of the substance makes it a veritable accumulation of heat, its high heat of melting (-80 cal) and heat of evaporation (+580 cal at 15 °C) make the surface of the earth despite minor fluctuations, a veritable thermostat. Temperature records throughout the year should be given to illustrate the small differences between tropical and subtropical climates (*e.g.*, from Humphreys). Temperature also determines the amount of water vapour the air may earn, and of course, also determines its density. The temperature factor is therefore, the most important in the physics of the atmosphere. The rivers and lakes, but more experimentally the ocean, vary much less in temperature, which the soil is still more conservative. Deep sea temperatures vary around 2-3 °C, deep freshwater lakes, of course, show the temperature of the maximum density of freshwater 3.98 °C. While in soil the "troposphere" (influences of weather) penetrates only 10-20 metres in water this sphere (epilimnion, tropolimnion) may be more than 100 m in thickness. Below that level, in soil, the temperature rises about 3 °C for every 100 m, so that, theoretically at a depth of 1,500 m, there should be an end of active life.

12 Thomas Frederick Colby (1784-1852), British major general and director of the Ordnance Survey, leading geographer of his time. Baas Becking referred to base line measurements with 'Colby's Compensation Bars'.

13 Reference to Johannes Schmidt (1877-1933), Danish biologist credited with discovering that eels (*Anguilla anguilla*) migrate to the Sargasso Sea to spawn: Schmidt (1923). See also Section 4, p. 138.

14 Reference to Humphreys (1920).

15 The town Verkhoyansk holds the Guinness world record for the greatest temperature range on earth: 105 °C. The lowest temperature recorded there in February 1892 was -67.6 °C.

2.2.7 Summary and conclusions

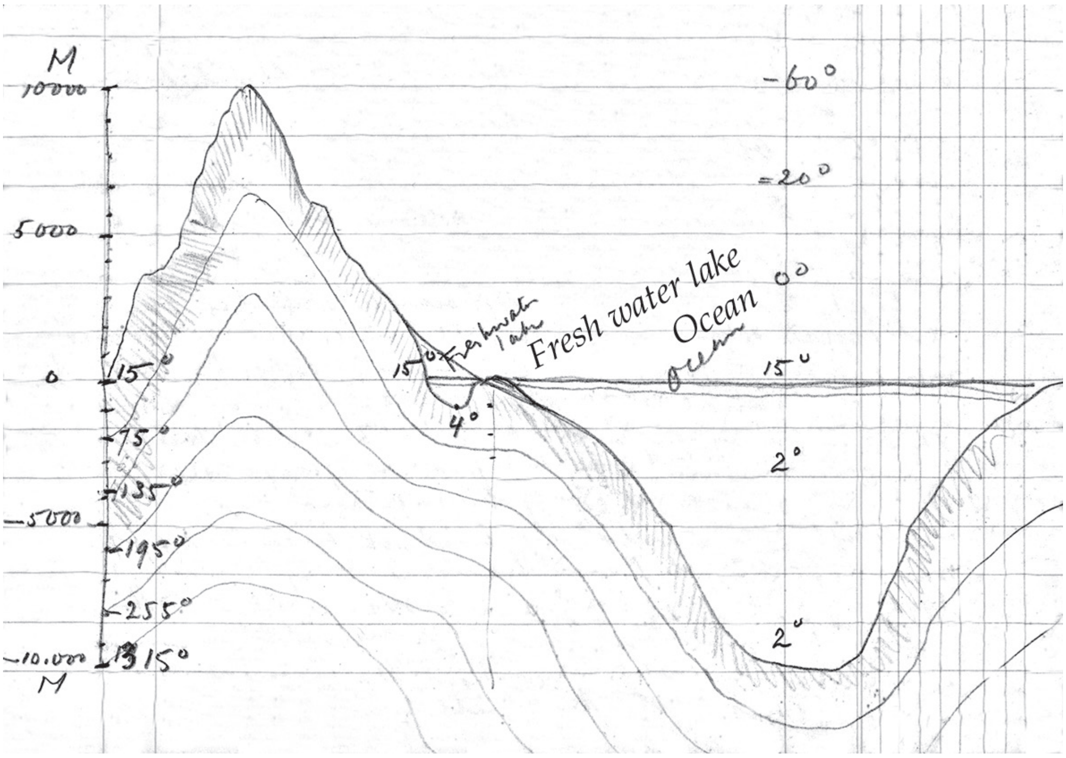


Figure 2.5 Temperature gradients in water, air and earth from 10,000 m height to 10,000 m depth.

N.B. This diagram should be corrected and amended with the aid of existing literature.

See also Section 5, for the oceanic and limnological condition.

2.3 Present Status: Geochemical

2.3.1 Introduction

According to Goldschmidt, the following elements are typical for the various zones described in Section 2.1.5 and on Figure 2.1 of this treatise. The core is siderophilic, the next layer is called chalcophilic and the outer layer is the atmosphere (Table 2.1).[16]

Table 2.1 Geochemical classification of elements. From Barth (1939).[17]

Siderophilic (zone 1) Fe, Ni, Co, P, (As), C, Ru, Rh, Pd, Os, Pr, Pt, Au, Ge, Sn, Mo, (W), (Nb), Ta.	**Chalcophilic** (zone 2) O, S, Se, Te, Fe, (Ni), (Co), Cu, Zn, Cd, Pb, Sn, Ge, Mo, As, Sb, Bi, Ag, (Au), Hg, Pd, Ru, (Pt), Ga, In, Te.
Lithophilic (zone 3) O, (S), (P), (H), Si, Ti, Zr, Hf, Th, (Sn,) F, Cl, Br, J, B, Al, (Ga), Sc, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Cb, Li, Na, K, Cs, Rb, Be, Mg, Ca, Sr, Ba, (Fe), V, Cr, Mn, (Ni), (Co), Nb, Ta, W, U, C.	**Atmophilic** H, N, C, (O), Cl, B, I, He, Ne, A, Kr, Xe. **Biophilic** C, H, O, N, P, S, Cl, J, (B), (Ca, Mg, K, Na), (V, Mn, Fe, Cu).

In the siderophilic zone there are 7/19, in the chalcophilic 8/26, in the lithophilic zone 21/54 biophilic elements, or 0.37, 0.31 and 0.40 of the total (Fig. 2.6).[18] The biosphere bears, therefore, no special chemical relation to the outer crust. From the atmospheric elements, however 7/14, or 0.50 show affinity. This might indicate that, apart from lithophilic H, the biosphere has been derived in part at least from the atmosphere. As compared with other celestial bodies, the earth is rich in iron. The oxygen in the outer shell would not suffice to oxidise the native iron of the core. After the various layers, like in an iron smelter, had separated, the temperature, according to some was too high even for oxides to form. Experiments with the electric oven have shown that at those temperatures, silicides, nitrides and carbides would form (Lénicque, 1903; cited by Clarke, 1916, p. 57). At lower temperatures, however, the oxygen began to combine. Nitride of iron, still exists in volcanic exhalations, but most of the nitrogen remained uncombined in the atmosphere. The oxygen must have been utterly depleted. Water was formed, and the original atmosphere should contain carbon dioxide, nitrogen, water vapour and volcanic hydrogen. Then the process of weathering began, by mechanical action of water, as vapour, then as liquid, much later as ice, and the weathering influence of carbon dioxide besides. Salts and silt are disintegration products of the eruptive accumulated in the primitive ocean. However, the early attempts of Halley (followed in modern times by those of Clarke, 1916),[19] to account for the composition of the ocean by rock leaching only, should fail, because of the preponderance of sodium over

16 Baas Becking revised and enlarged the section about the present geochemical status of the earth in his 1953 manuscript of *Geobiology*, Chapter I, p. 70-74.

17 Baas Becking referred to table 14, p. 15, in *Die Eruptivgesteine* by Barth (1939).

18 Figure 2.6 is based on Van Tongeren (1935, p. 307).

19 Reference to the third edition Clarke (1916), *The Data of Geochemistry*. Baas Becking also referred to Clarke as an important source in *Geobiologie* (1934), Chapter IX *Oceans*. In the Utrecht prison he probably had a copy of Clarke's report.
Clarke referred to Lénicque (1903).

chlorine in eruptions, while in the ocean their concentration is similar (Correns, 1939).[20] It may be that the chlorine in the ocean is for a large part at least of volcanic origin.

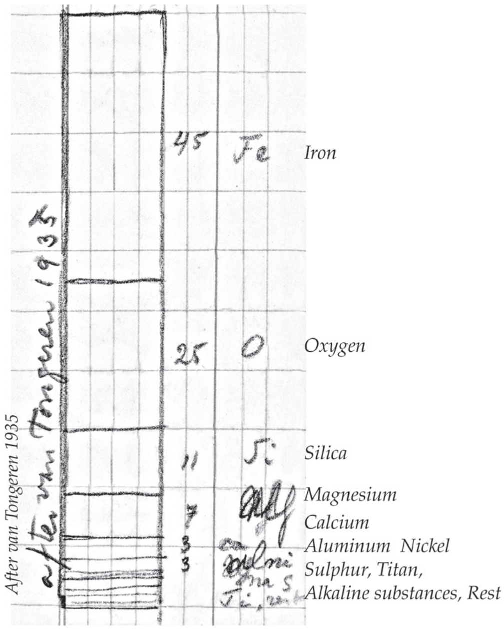


Figure 2.6 Probable composition of the earth in percentage by weight (after Van Tongeren, 1935). Iron (45), oxygen (25), Silica (11), Magnesium (7), Calcium 3, Nickel 3, Aluminum, Sulphur, Titan, Alkaline substances, Rest.

The elements of the earth crust are almost all of low atomic weight (Fig. 2.7). The economically important, heavy metals being accumulated in the core in the regular shell. The shell is preponderantly of eruptive characters, the sediments forming only ±5 % of the 10 mile outer crust, of the lithosphere, roughly three quarters is represented by aluminium silicates, the other metals appearing only as a sort of cementing substance. Following in importance is water, on the total ±9 %. Carbon, for our consideration the most important element, only has a frequency on the entire crust of 0.18 %.

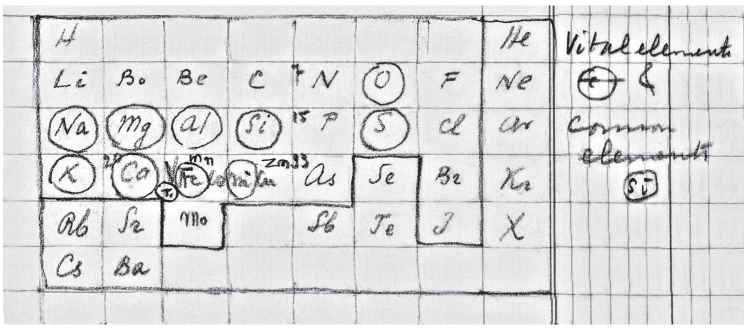


Figure 2.7 "Vital" and "common" elements in the earth crust.

2.3.2 Cyclic changes

Only those elements that are geochemically "mobile" are of interest for our problems. According to Vernadsky (1924, *Geochemistry*) all of the crustal elements enter into a cycle. As an example, we take the iron (Fig. 2.8). Processes surrounded by a line are biological.

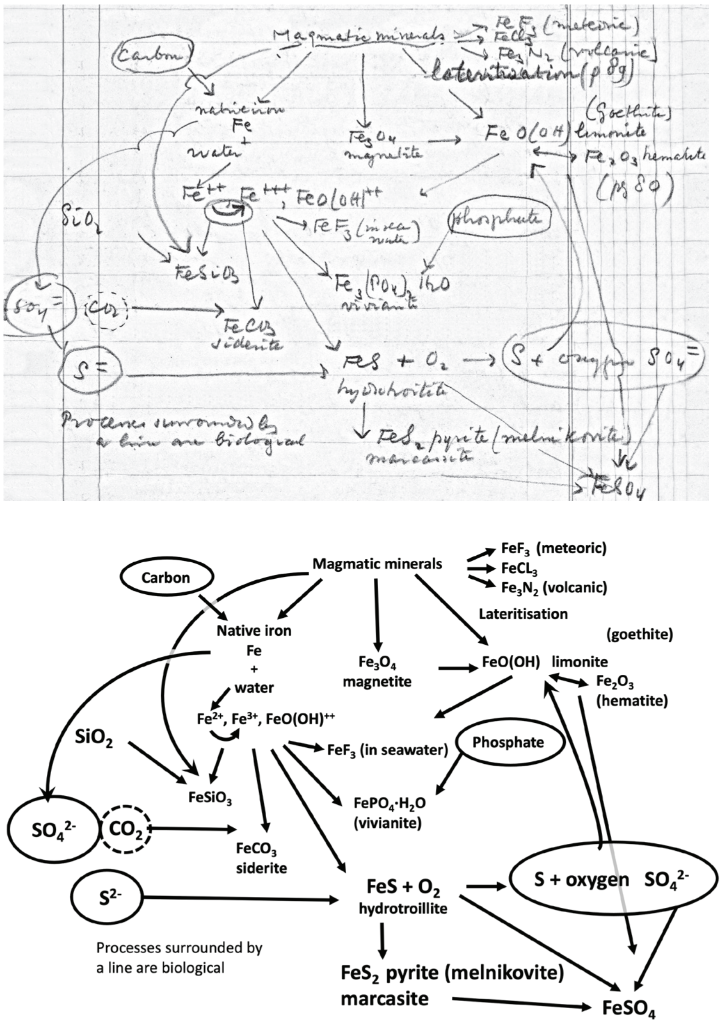


Figure 2.8 Geochemical "mobility" of iron in the earth crust.

The outer shell of the earth is an oxidised shell, although a great many substances are in a reduced state, the overwhelming majority are present in the highest oxidation stage possible. Notable exceptions, of course, form sulphides in the magna, further such substances as CO and H_2 on volcanic exhalation, ferro-salts and ammonia, nitrites, sulphites *etc*. The reductive processes in the sedimentary layer of the lithosphere and the hydrosphere are probably entirely biological. It is the biosphere, and in the biosphere the plant cells, which function as the great reducing agent, for the oxidised environment.

See also Sections 3.8.12, 3.12.1 and 3.12.2.

20 Baas Becking referred to Correns (1939).

2.3.3 Vital elements

Due to the oxidic character of the outer shell it seems plausible, like Correns (1939) does, to write the equation of a compound like glauconite as $K_2(MgO.FeO)Fe_2O_3$ Al_2O_3 8 SiO_2 3 H_2O.[21] Such an equation stipulates the oxidic nature of the lithosphere sufficiently, no less than 7 different oxides in a combination of 17 oxides being present! Nitrogen alone is geochemically too inert to react, except at very high temperatures (nitrites in volcanic exhalations), but living cells are able to attack nitrogen as well. Not only the metals but also the other substances are found chiefly in the highest oxidation state; carbon as CO_2, sulphur as sulphate, phosphorus as phosphate, nitrogen as nitrate, silicon as silicate. Oxygen pervades therefore the entire outer shell of the earth, reducing thereby, in the majority of cases, the energy potential of the substrates to a low level.

2.3.4 Summary and conclusions

Apparently, the earth crust contains chiefly the lighter elements. Oxygen is by far the commonest; it not only pervades the outer shell, but also reacts with almost all other elements. For the oxidation of the central core of the earth however, our atmospheric oxygen would be insufficient. The commonest substances on earth are Al_2O_3, SiO_2, Fe_2O_3 and H_2O. Most of these substances only represent phases in a cycle, however. Such a cycle is illustrated diagrammatically for the iron. It is mentioned that only plant cells are capable of reducing the outer environment, thereby setting up a certain energy potential necessary to contain life of plants and their dependents: the animals.

2.4 Lithosphere, Biosphere *etc.* [22]

2.4.1 Introduction

Geobiology is concerned with the outer shell of the earth, taking into account the deepest oceanic depth. Therefore, a shell, about 10 miles thick (16 km) has to be considered. The solid crustal matter we call the *lithosphere*, the thin larger of liquid in it (ocean and freshwater) the *hydrosphere*, while the gaseous envelope, the *atmosphere* is weakly held by gravity (Table 2.2).

Table 2.2 Composition of known matter of the earth. The mean density of the rocky crust was assigned not lower than 2.5 and not much higher than 2.7. After Clarke (1916).

Density of Crust		2.5	2.7
Atmosphere	percent	0.03	0.03
Ocean	ditto	7.08	6.58
Solid Crust	ditto	92.89	93.39
		100.00	100.00

In the table the relative importance of those shells is given. The *biosphere*, the thin film of green space spread over lithosphere and pervading the *hydrosphere*, cannot properly be estimated. It would only amount to a very small correction in the above figures, however. Although quantitatively unimportant, this essay tries to show the great influence of the biosphere upon earth.

2.4.2 Atmosphere

Table 2.3 Composition of the atmosphere in percentage.

		By weight	By volume
Oxygen	percentage	23.024	20.941
Nitrogen	ditto	75.539	78.122
Argon	ditto	1.437	0.937
		100.000	100.000

Max. equivalent to 1,268,000 cubic miles of water, its composition, according to Sir William Ramsay is together with other substances in small amounts, such as H_2S, H_2, NH_3, HNO_3 benzene, dust, organic remains and, of course, water vapour.[23] The other rare gases krypton, xenon, helium and neon are present in very small quantities. Carbon dioxide is always present in small quantities. Although this gas is so much active in the earth's metabolism the percentage is remarkably constant (0.02910 – 0.03027 % by volume). The oxygen varies also little, the atmosphere is slightly richer in oxygen near the poles (variation from 20.720-21.180 vol. %). By electron discharge, oxides of nitrogen may be found, yielding nitrous and nitric acids. "All the nitrogen of organic matter came originally from the atmosphere" (Clarke, 1916). Hydrogen always occurs in the atmosphere, in varying amounts (1:5,000 max). SO_2 also occurs in the air, probably an industrial contamination chiefly. The carbon dioxide in the atmosphere amounts to 2.2×10^{12} metric tons, corresponding to 6×10^{11} tons of carbon. A city like Paris generated, in $18{,}443 \times 10^6$ m^3 CO_2 daily. The annual consumption of coal ($\pm 2 \times 10^9$ tons) adds to the atmosphere, therefore, no more than 0.001 of its CO_2 addition of CO_2 to the atmosphere is possible through the combustion of carbonaceous meteorites. Much CO_2 is taken up by the weathering of rock (e.g., orthoclase from kaolin) according to T.C. Chamberlin, 10^9-10^{10} tons of CO_2 are withdrawn annually from the atmosphere, by rock weathering and by carbon dioxide assimilation of green plants.[24] The water vapour in the atmosphere is of course variable and requires special treatment (see Section 5.10.4).

2.4.3 Lithosphere

Mass of the 10 mile rocky crust: 1,633,000,000 cubic miles, max density 2.6 is *magnetic* (see also Section 3.8, *Salts and Inorganic Substances*), chiefly a rigid crystalline structure, according to Barth (1939, after Goldschmidt) an oxygen lattice held together by cations. Oxygen has, with potassium the

21 Reference to Correns (1939, p. 208-209). Glauconite has the chemical formula, $(K,Na)(Fe^{3+},Al,Mg)_2(Si,Al)_4O_{10}(OH)_2$.

22 In his 1953 version of *Geobiology* Baas Becking enlarged and revised the section about the lithosphere (Baas Becking, 1953a, Chapter I, p. 74-83).

23 Sir William Ramsay (1852-1916), Scottish chemist who discovered the noble gases and received the Nobel Prize in chemistry in 1904 "in recognition of his services in the discovery of the inert gaseous elements in air".

24 Reference to a publication of Thomas Chrowder Chamberlin (1843-1928), American geologist. *An Attempt to Frame a Working Hypothesis of the Cause of Glacial Periods on an Atmospheric Basis* (1899). In this study Chamberlin developed at length the idea that changes in climate could result from changes in the concentration of atmospheric carbon dioxide.

largest atom![25] It has often been neglected by mineralogists, but if we plot the frequency not of mass, but of volume, we arrive at most interesting results! (Table 2.4)

Table 2.4 Composition of the Lithosphere. After Barth (1939).

	Weight %	At %	Vol %	Atom radius in A
O	46.59	62.46	91.77	1.32
Si	27.72	21.01	0.80	0.39
Al	8.13	6.44	0.76	057
Fe	5.01	1.93	0.68	0.82
Mg	2.09	1.84	0.56	0.78
Ca	9.63	1.93	1.48	1.06
Na	2.85	2.66	1.60	0.98
K	2.60	1.43	2.14	1.33
Ti	0.63	0.28	0.22	0.62

Question *atom* radii are different from *ionic* radii. How did Barth (1939) get them mixed up?

2.4.4 Lithosphere sediments

At first sight it looks as if, when we consider *volume*, the bioelements should gain in importance as the sequence becomes O-K-Na-Ca-Si-Al-Fe-Mg. However, the atomic ratio of other bioelements is quite small (C = 0.16, N = 0.14, P = 0.35 and S = 0.33 Å apparently). As volume elements they would recede even further down in scale! However, the role of the elements named by Barth (1939) is enhanced. Tables 2.4 and 2.5 on the composition of the elements in the lithosphere, were taken from Clarke (1916, *Data of Geochemistry*, p. 33). A rough estimate shows that 95 % of the lithosphere consists of igneous rock, 5 % of sedimentary (Table 2.6). Of the sedimentary rock, 4/5 is shale, and the remainder, the amount of sandstone is about here 1/5 times that of limestone. Weathering is, therefore a superficial process. Of the outer shells, the lithosphere occupies 93 %.

Its average composition, in terms of elements, is again given below (Clarke, 1916, p. 35). (The sequence is that of the average for all spheres, including atmosphere and hydrosphere). Bromine for instance is a typical hydrospheric, nitrogen an atmospheric, element. The outer shell, the lithosphere, which concerns us is rather poor in bioelements. Taking the chief ones O, H, P, N. S, Ca < K, Fe, Na < Mg, we see that they practically all are "high" in the scale (among the 20/92 highest). Their average number is 9/92, taking the bioelements in the widest sense, including Mn, Al, Si, Cl, P, Sr, F and moreover Cu, Co, Ni, Mo and V we still see *that the overwhelming majority of the bioelements lies among the common elements.* We shall deal with this matter more fully. The change from eruptions to sedimentary shall be dealt with in Section 4.3, based on Correns (1939). There also soil formation will be considered.

Table 2.5 The average composition of terrestrial matter in lithosphere in percent.

O	47.33
Si	27.74
Al	7.85
Pl	4.50
Ca	3.47
Mg	2.24
Na	2.46
K	2.46
H	0.22
Ti	0.46
C	0.19
Cl	0.06
Br	
P	0.12
S	0.12
Ba	0.08
Mn	0.08
Sr	0.02
N	
F	0.10
All others	0.50

Table 2.6 Composition of lithosphere.

Igneous		95%
Sedimentary	Shale	4.0%
	Sandstone	0.75%
	limestone	0.25%

2.4.5 Hydrosphere

Water may be vadose (or meteoric) or juvenile, coming from the magna. In the biosphere we also know metabolic water, which originates from combustion of organic substance. The meteoric water is cyclic and is almost quantitatively present in the ocean. The freshwater does not influence it much, but annually there is contribution from the rivers to the ocean, both in salt and in silt. In 106 metric tons, we give Karsten's estimates of annual contribution of the rivers to the ocean (Table 2.7).[26]

It may be assumed that most of the carbonate, sulphate, calcium and nearly all of the iron, aluminium and silica precipitate. Furthermore, the rivers concentrate silt to the ocean. Humphreys and Abbot (cited by Clarke, 1916) estimate the annual amount of silt contributed by the Mississippi at approximately 370 × 10^6 metric tons. The Nile contributes about one seventh of this amount.

25 Baas Becking referred to Barth (1939), *Eruptivgesteine* on igneous rocks. He copied Table 2 from Barth (1939). Thomas F.W. Barth's view was that igneous rocks and the whole lithosphere are to be regarded as essentially a packing of oxygen ions. The accumulation of this huge volume of oxygen is made possible by the cations, which occupy the interstices and with their electrical charges, keep the whole structure together although their volume is comparatively insignificant. Also see Barth (1948).

26 Baas Becking possibly referred to George Karsten (1863-1937), a German botanist who described the phytoplankton in oceans, based on the results of the German Deep Sea Valdivia Expedition (1898-1899), in three volumes 1905, 1906 and 1907.

Table 2.7 Annual contribution from rivers to the ocean according to George Karsten.

CO_3	10^6 ton
SO_4	961.350
Cl	332.030
NO_3	155.350
Na	24.614
K	258.357
Ca	57.982
Mg	557.670
Fe_2O_3	93.264
Al_2O	75.213
SiO_2	319.179
	2.735 × 106 ton

Murray estimates the total rainfall at ±30,000 cubic miles; approximately 3 × 10^9 tons of drainage are carried to sea. Waters from crystalline feldspathic rocks show a high amount of Na and K, low concentration and a high amount of SO_2. Water from sedimentary regions, especially in limestone areas, shows a high proportion of Ca and Mg. Acid waters occur wherever there is organic matter together with very low concentrations of minerals and further in volcanic regions or where sulphides oxidise by bacterial action. But as spring water starts its travel to the ocean, its composition changes on the way. It may meet other wells, it may traverse regions of drainage or irrigation, industrial and domestic pollution may all show their influence. In this essay we shall revert to this problem several times, enough to state that usually the river water is characterised by preponderance of Ca^{2+} and HCO_3-, while in the ocean water Na^+ and Cl^- predominate in the series (Table 2.8).

Table 2.8 Differences in composition: rivers and ocean.

	$Ca^{2+} > Mg^{2+} > Na^+$		$Na^+ > Mg^{2+} > Ca^{2+}$
Rivers		**Ocean**	
	HCO_3- > SO_4^{2-} > Cl^-		Cl^- > SO_4^{2-} > HCO_3-

2.4.6 Hydrosphere ocean

The volume of the ocean is about 300,000,000 cubic miles (1,286,000,000 cubic kilometres). The composition of oceanic water is remarkably constant. The following Table 2.9 is from Wattenberg (1938),[27] gives the composition 19‰ Cl or 34.33% salt (Knudsen equation, see Section 3.13.3).[28]

Table 2.9 Composition of oceanic water according to Wattenberg (1938).

Cations	g/kg	millimol/kg	Anions	g/kg	millimol/kg
Na	10.47	455.0	**Cl**	18.97	535.1
K	0.38	9.7	**Br**	0.065	0.81
Mg	1.28	52.5	**SO_4-**	265	27.6
Ca	0.41	10.2	**HCO_3-**	0.14	2.35
Sr	0.013	0.15	**BrO_3**	0.027	0.44
Cation meq 0.5904; Anion 0.5943 ????					

The surface waters are always oversaturated with $CaCl_3$. A great number of minimum substances occur in seawater, which are given in Table 2.10 in γ/L [= 10^{-6}g/l].

The ocean cannot, as has repeatedly been tried, be considered as a rock leach product, however as Na and Cl appear in quite a different proportion as found in the rocks. The same is true of boron. Perhaps part of the chloride is derived from volcanic action. The attempt to derive the age of the ocean from the accumulation of NaCl seems therefore futile. Apart from freshwater and seawater we meet with solutions of higher salinity; the brines, as an abode of life they represent various remarkable extremes. When we take the ions Na^+, K^+, Ca^{2+}, Mg^{2+}, $Fe^{2+ (+)}$, HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-} and SiO_3^{2-}, we may build a great number of these really possible solutions, only part of which are realised in nature. Nature therefore, as a butler, only provides the biosphere with a limited number of drinks (see also Section 3.1). We shall see that this terrestrial milieu is always more limited as the potential milieu. Several organisms find their optimum in a liquid laboratory milieu, which is not present in nature.

2.4.7 Biosphere

(Estimate of quantity of living matter??)

The annual yield in organic matter (in land as well as in the ocean) may be estimated roughly as 1 ton/hectare 1 Ha = 108 m^2, the earth is 5.12 × 10^{18} m^2, or the yield in organic matter should be 5 × 10^{10} tons, or more than all the river water moving to the ocean! Of this production we put 2/3 on plankton and its derivatives, and the remainder on grassland and forest and their derivatives (animals). Here we do not take into consideration the large beds of kelp[29] or the bacterial action in soil and sediment, nor do we estimate human activity entirely from the rest of the biosphere and coin a new term "anthroposphere".

Table 2.10 Composition of surface waters in γ/L [10^{-6} g/litre].

				Au	0.04			**Mo**	0.5	**Br**	65000	**Si**	10-1500	NB 5-50 (Wattenberg)
				Ra	10^{-7}			**Ag**	0.3	**B**	4700	**Se**	4	
Sr	13000	**Li**	110	**Zn**	5	**Cs**	2	**V**	0.3	**F**	1400	**P**	1-60	
Rb	200	**Ba**	50	**Mn**	5	**U**	2	**Ni**	0.1	**J**	50	**NO_3**	1-6000	
Al	125	**Ar**	5	**Fe**	2	**Th**	<1	**Hg**	0.03	**As**	15	**NO_2**	0.1-50	

27 Reference to Hermann Wattenberg (1901-1944), chemist on board on the German *Meteor* expedition in the Southern Atlantic Ocean (1925-1927). In 1944 he was the director of the Institut für Meereskunde in Kiel that was totally destroyed by bombing in which occasion Wattenberg and eight of his colleagues lost their life.

28 An equation in fluid dynamics developed by Martin Hans Christian Knudsen (1871-1949), a Danish physicist at the Technical University of Denmark.

29 Kelp are fast growing brown algae seaweeds (order *Laminariales*) that live in submerged forests near the ocean shore.

2.4.8 Summary and conclusions

In the foregoing a very brief survey is given of the composition of the atmosphere, the lithosphere and the biosphere. Certain substances are common to all spheres, to wit ***water*** and ***carbon dioxide***. They are of the inorganic world, as well as of the organic, the central substances. In the lithosphere we meet further ***SiO_2*** and ***aluminium silicates*** in the hydrosphere ***sulphate*** and ***sulphide*** and ***oxygen***. In the atmosphere ***oxygen*** and ***nitrogen***. A natural division of different types of water does not exist, the usual classification (Palmer, 1911; Clarke, 1916) is cumbersome.[30] It may be more logical to classify the water according to pH as the solubility of many substances is a function of the H+ concentration (Table 2.11).[31]

Table 2.11 Classification of water according to pH.

pH	
0-3	Sulphuric (Volcanic acid or bacterial)
3-5	Hydrochloric (vole) Peat bog
5-6	Chalybeate and ombrogenic
6-8	Soft water
8.2 - 10	Bicarbonate hard waters
10	Alkali carbonate

2.5 Comparison with Other Planets

2.5.1 Introduction

Vehicular substances. The earth with its two major dictating influences; gravitational field and incident radiation, enables *water* to occur in the liquid phase. Water is a most unusual substance and it will take a part of a book to describe its properties, which make it such an ideal substance. Let us call it a vehicular substance; it carries substances in solution, and in colloidal solution. It is the medium of chemical reactions. It is the medium of life. It's dielectric construct, it's dissociation, it's thermal properties make life on this planet possible. The question arises whether there are other possible substances which may act as vehicular? Both E.C. Franklin, the creator of ammonia chemistry, and Lawrence Henderson have answered this question: There is another, but probably not more than one other, such substance: liquid ammonia.[32]

2.5.2 Ammonia chemistry

A vehicular substance be HV, as compound:

Acid + Base = Salt + HV

or

HCl + NaV = NaCl + HV,

in the case of liquid ammonia, which is, at -70 °C (or at room temp., 90 kg pressure) highly ionised, we get:

$HCl + NaNH_2 = NaCl + NH_3$.

Franklin has given us (1932) an ammonia chemistry, which logically proceeds, parallel to the aqua chemistry, to chemical reactions and compounds.[33] For instance, in aqua chemistry carbonic acid is:

```
 OH        NH2       NH2
 /         /         /
C = O    C = NH    C =O
 \         \         \
 OH        NH2       NH2
aqua      amino    aqua-amino
```

Liquid ammonia is an ideal solvent, almost like water. It is highly ionised and takes part in reactions like water does, at -60 °C reactions go with fairly great velocity. So, the low temperature does not inhibit the reaction too much.[34]

2.5.3 Conditions on Venus

Now if a vehicular substance exists on another planet, it may be that life could also occur there. J. Russell of Princeton has given (*Nature,* 1939) a description of planets chemical conditions.[35] Only these planets should be considered, Mercury being too near the sun, Saturn, too far off. The most interesting fact that Russell reports about Venus is that its atmosphere contains oxygen. Now if Goldschmidt's hypothesis (Section 2.1.2) about the origin of atmospheric oxygen be true, all of this gas should be derived from the photosynthetic decomposition of water, as in the atmosphere of the cooling earth no oxygen occurred, all of it being fixed in the oxides of the stony crust. If the temperature on Venus is not too high (clouds of water vapour, which are reported, may affect such a screen) and Goldschmidt's hypothesis be acceptable (which to the author it is), there is no reason why Venus should have behaved differently – and there is therefore no reason why no life should occur on Venus (H_2O vehicular substance).

2.5.4 Conditions on Mars

Whether or not the canals "exist" is still an open question. The white polar spot, which partly disappears in summer, is indicative of melting ice, oxygen and water vapour have

30 The references are to Palmer (1911), Clarke (1924) and Clarke (1916).

31 In 1938 Baas Becking published *On the Cause of the High Acidity in Natural Waters, especially in Brines* (Baas Becking, 1938a), in which the Kawah Tjewedéh a hot volcanic lake in Central Java is described that he visited in May 1926 and where a pH = 2.98 could be determined electrometrically.

32 Baas Becking referred to Chapter VII of Laurence Henderson (1913), *The Fitness of the Environment*, in which he included (p. 263-265) an extensive note about the studies on the properties of liquid ammonia as a solvent by Edward Curtis Franklin (1862-1937) and his students in the first two decades of the 20th century. Franklin was a Professor of Chemistry at Stanford University.

33 The reference is to Franklin (1935). In his 1953 manuscript *Geobiology* (Chapter I, p. 56) Baas Becking referred to Franklin as follows:

> The late E.C. Franklin of Stanford University, is the originator of 'ammonia chemistry' and in his monograph (1934) *The System of the Ammonia Compounds*, he has initiated us into a new chemical world where an acid plus a base yield a salt plus ammonia. Franklin not only theoretically translated the aqueous system into the ammonia system, but he showed experimentally that whole series of analogues exist. For instance, the analogue of carbonic acid in the ammonia system is guanidine.

34 For Baas Becking's fascination with the ammonia chemistry see paragraph *Ammonia Chemistry* in the introduction to this transcript of *Geobiology*.

35 Henry Norris Russell (1877-1957), Professor of Astronomy and director of the Princeton University Observatory, pioneered in the use of atomic physics for the analysis of the stars and thus played a principal part in laying the foundations of present day astrophysics. He analysed the physical conditions and chemical compositions of stellar atmospheres and evaluated the relative abundance of the elements. Russell published between 1923 and 1954, 43 papers on the analysis of laboratory spectra, which laid the groundwork for the modern study of stellar atmospheres, envelopes and nebulae. His assertion of the overwhelming abundance of hydrogen was accepted, after prolonged controversy, as one of the basic facts of cosmology.
See Payne-Gaposchkin (1977, p. 15-18).
Baas Becking's reference to a *Nature* publication in 1939 was not confirmed by me; it is possible that he refers to Russell (1935).

been demonstrated in the atmosphere. The same experiments as given about Venus pertain here. Older astronomists report the presence of chlorophyll (leaf green) on Mars! In a written communication to Prof. E. Hertzsprung of Leiden,[36] Russell declares that even by means of modern telescopes chlorophyll could not be demonstrated with any degree of certainty. Therefore, we have to rely on the indirect evidence of the oxygen. At least two other planets, besides the earth, show therefore evidence of being inhabited! If we include the possibility of other vehicular substances, we have also to take into account the conditions on Jupiter.

2.5.5 Conditions on Jupiter

Here there seem indications of absorption bands of methane, nitrogen and ammonia. As the surface temperature is low, methane and ammonia are both in the liquid state. Now methane is a very inert liquid indeed, being a paraffin and as such unlikely to be active as a vehicular substance. But as we have seen, liquid ammonia has many characteristics in common with water. It has a high dielectric constant, it is considerably dissociated into ions, it seems an ideal solvent for both inorganic and organic compounds. Its thermal properties are less extreme than those of water, but still, these would be sufficient thermostatic actions. The possibility of an "ammonium life" on Jupiter, if the solar energy should suffice, should be reckoned with.

2.5.6 Summary and conclusions

Even if we accept water being the only vehicular substance for life, at least two other planets, Venus and Mars, show the presence of oxygen in their atmosphere. The oxygen may only have originated in one way, namely by the decomposition of CO_2 and water either under the influence of sulphate or by other (chemical) means (see Section 3) If we allow for other possible vehicular substances (about which biological experimentation is unfortunately lacking), Jupiter has to be considered as well. The problem about the habitability of other planets is an old one, but it has received new impulses from three sides,

- primo, the spectroscopic observations of Russell,
- second, the oxygen hypothesis of V.M. Goldschmidt and,
- tertio, the creation of ammonia chemistry by E.C. Franklin of Stanford University.

2.5.7 On the origin of life

(Kluyver, *'s Levens Nevels*, 1937).[37]

Some great man ("Darwin") has said "it is mere rubbish to speculate on the topic of life, one might as well speculate upon the origin of matter."[38] The latter has been done and abundantly and it has been, as far as the author is aware, no rubbish. Let us see what *may* be said about the origin of life upon this earth. If water was the vehicular substance the temperature should have been below 100 °C. There was hardly any oxygen in the air, only CO_2, hydrogen and so much water vapour that there was hardly any sun. Do we know of organisms that are capable to live under these conditions? A great many bacteria are able to assimilate CO_2 by means of hydrogen. This reaction is weakly exothermic (3,000 cal):

$$CO_2 + 4H \rightarrow HCOH + H_2O$$

$$(HCOH\ \Omega\ 1/6\ C_6H^{12}O_6)$$

The sulphate reducing organism, *Sporovibrio desulfuricans*,[39] still a cosmopolitan, may perform this feat. Such an anaerobic autotroph might have been the beginning of things which much later, when light shone, photosynthesis made its appearance, perhaps with other bacteria-like things like the purple bacteria and the bluegreen algae. The purple worked according to:

$$CO_2 + 2\ H_2S \rightarrow HCOH + 2\ S + H_2O$$

and the bluegreens:

$$CO2 + 2\ H_2O \rightarrow HCOH + O_2 + H_2O$$

Here the oxygen was being developed. So, any hypothesis that starts with a non-chemosynthetic, aerobic organism as the initiator of life on this planet, does not take into account the geochemical evidence at hand. These exist a number of "borderline" organisms, too small to be observed (virus, phage *etc.*). As they are probably not even organisms, but in any case, that they have always to parade when the origin of life is mentioned, is beyond the author's understanding.[40]

36 Ejnar Hertzsprung (1873-1967), Danish astronomer from 1920-1945 Professor of Astronomy in Leiden. He is known by the Hertzsprung-Russell diagram, showing the relationship between the star's absolute luminosities *versus* their stellar classifications or effective temperature.

37 Baas Becking referred to the palindrome in Dutch ('s Leven Nevels [Life's Fringes]) of the address by the Dutch microbiologist Albert Jan Kluyver (1888-1956) in 1937, where he spoke at the Congress of Microbiologists on the status of virus research in the Netherlands at that time. See Kluyver (1937).

38 In the 1953 version of *Geobiology* Baas Becking wrote:

> In 1887 Charles Darwin, in a letter to Sir Joseph Hooker, stated "it is mere rubbish to talk about the origin of life; one might well talk about the origin of matter". A great master realised the futility of arguing on little evidence. As, however, the talk about the origin of matter has culminated in the recent theories of Bethe and von Weiszäcker, which account quantitatively for such processes as the energy production of our Sun, the question arises whether it is still devoid of sense to talk about the origin of life. We know now that matter builds itself from such corpuscles as protons by cyclic processes and that, at the disintegration stage of a star, when all protons have been changed into helium and positrons, the heavier elements, in thermodynamic equilibrium in the core of the star, are distributed over space. As life has a specific material carrier, the origin of life has to follow the origin of matter. And in as much as matter has originated, life has to follow, and a question which seemed mere rubbish seventy years ago seems pregnant with meaning today.

In an unpublished draft, A Budget of the Earth (Baas Becking, *circa* 1953), he entered the reactions of nuclear fusion and the carbon-nitrogen cycle nuclear process, based on a 1938 article by Hans Albrecht Bethe and Charles Critchfield on energy production in stars through nuclear fusion. Stars radiate by fusing hydrogen nuclei (protons) into helium-4 nuclei *via* proton-proton cycle.

Hans Albrecht Bethe (1906-2005) German-American nuclear physicist, who won the Nobel Prize in Physics in 1967. In 1939 Bethe and Carl Friedrich von Weizsäcker (1912-2007) independently described the core process of the carbon-nitrogen cycle, fusing hydrogen to helium with carbon, nitrogen (N) and oxygen (O) as a catalyst.

39 The reference is to a sulphate reducing bacteria described by Beijerinck (1895) as *Spirillum desulfuricans*. The present generic name is *Desulfovibrio*. Baas Becking probably also referred to the first chapter in Baars (1930), where the generic name is *Vibrio*.

40 In Australia Baas Becking gave two lectures on the *Origin of life* (Sydney 1951 and Melbourne 1959). Baas Becking (1951a, 1962).
In his preparatory notes for the 1959 lecture in Melbourne Baas Becking wrote several comments on Darwinism:

> Darwinism is essentially an aristocratic theory. The best, the rule.
> Eugenics is a logical consequence of Darwinism.
> And this is the reaction of the outer world. For some reason Darwinism has become part of the British cultural heritage, while Lamackism quite penetrated the French bastion.
> For a Victorian gentleman Darwinism was the only revolutionary outlet.

3. THE MILIEU

3.1 Potential, Natural and Terrestrial

The limits of the milieu for a certain organism strictly pertain to a certain stage in its development. The milieu for a larva and for an imago may be different. Still, we might consider an integration of the boundaries for a certain stage, as long as that stage requires a constant milieu. Geobiologically this is an organism distinct from another developmental stage. *Potential milieu* is limited by the faculties of the organism itself. These faculties, these properties, may never be ascertained completely. Dr. B. Hubert, for example, found a fungus (*Oospora*) growing on a solution (8 %) of vanadium chloride.[1] It seems improbable that the faculty to withstand this chemical is known of many other organisms. Temperature, pH, radiation and pressure range should be equally investigated, and the influence of every known chemical. It seems clear therefore that the boundaries of the potenti[illegible]
The picture we obtain of the organ[illegible]
laboratory milieu, shows a much mo[illegible]
boundaries. We may encounter a ce[illegible]
localities, the area total of the envi[illegible]
localities we call the *natural milieu*. [illegible]
organism in question may be limite[illegible]
of *Opuntia*, rabbits, wild cats *etc*.),[2] that there are large tracts of this earth equally suitable. If we take those into account, we widen the milieu limits again to the *terrestrial milieu*. The accompanying graph (Fig. 3.1) illustrates the idea.

2 In the introduction of Geobiologie (1934) Baas Becking referred to his example of 'natural environment'. In the translation from 2016 (p. 5):

For example, the Opuntia (paddle cactus) and the rabbit were given perfect opportunities for expansion in Australia, as were muskrat in Europe and the wild oat in California.

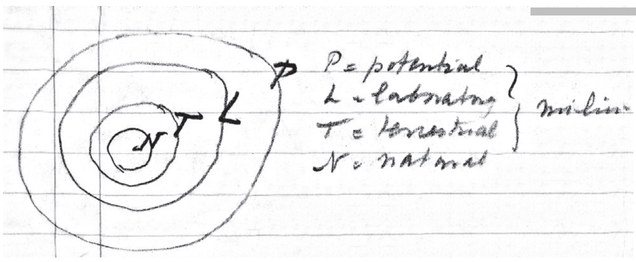


Figure 3.1 Limits of the natural (N), terrestrial (T), laboratory (L) and potential (P) milieu.

In this book we shall, as far as possible, carefully designate which type of milieu is meant. If for a number of organisms, the laboratory milieu is known, the simultaneous occurrence of these organisms in nature often gives a sufficient description of the milieu, even without subsequent chemical analysis!

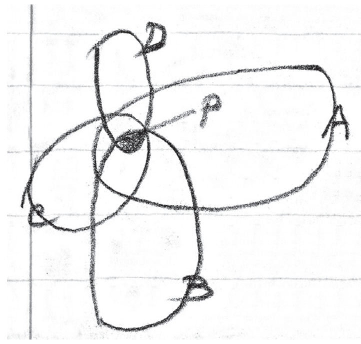


Figure 3.2 Milieu boundaries of four organisms A, B, C, D. P is "common denominator" of the milieu for the four organisms.

In the Figure 3.2, A, B, C and D represent milieu boundaries of four distinct organisms, it is clear that the "common denominator" (P) only gives a close description of the milieu. Inversely, by knowing the properties of a certain milieu, we may predict the occurrence of certain organisms.

[illegible] (Fig. 3.3) a biocoenosis of the solar
[illegible] milieu factors salinity, acidity and
[illegible] red. The boundaries of a number

[illegible] phyllopod *Crustacaea.*

[illegible] a polyblepharid, green flagellate.

L = *Lochmiopsis sibirica*, a filamentous, green alga.

B = Purple *sulphurim spirullaria.*

N.B. Dunianella viridis occurs over the entire area.

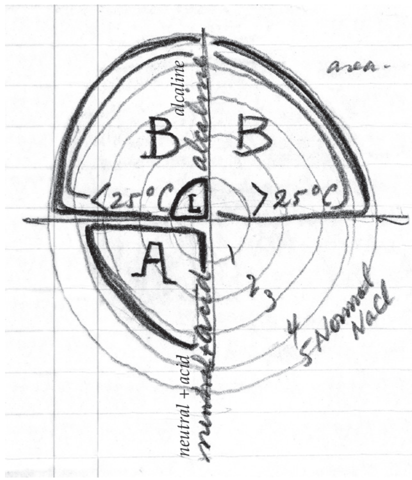


Figure 3.3 Biocoenosis of dollar salt works. Milieu factors are salinity, temperature, alkalinity and acidity. A = *Artemia salina*, a phyllopod *Crustacaea;* D = *Dunaliella viridi*, a polyblepharid, green flagellate; L = *Lochmiopsis sibirica*, a filamentous, green alga; B = Purple *sulphurim spirullaria. N.B. Dunianella viridis* occurs over the entire area.

1 B. Hubert was a PhD student of Baas Becking in Leiden. His experiments with *Oospora* were not retraced. Baas Becking (1935, p. 103-104), referred to studies in the Leiden Botanical Laboratory on the potential salt environment of the salt fungus *Oospora halophila* (Beyma) to the later fisheries biologist in the Dutch East Indies Dr J. Reuter. Reuter finished his PhD study in Leiden in 1936 with a thesis about the Malaria mosquito. Reuter (1936).

2 In the introduction of *Geobiologie* (1934) Baas Becking referred to his example of 'natural environment'. In the translation from 2016 (p. 5):

> For example, the Opuntia (paddle cactus) and the rabbit were given perfect opportunities for expansion in Australia, as were muskrat in Europe and the wild oat in California.

3 The example is based on Baas Becking's own research in the Jacques Loeb Laboratory of Stanford University, the research of Jacoba Ruinen in Leiden and of Cornelis B. van Niel in the Jacques Loeb laboratory. In *Geobiologie* (1934) the organisms in the example are discussed on various pages. See Boone and Baas Becking (1931), Baas Becking (1931a), Baas Becking (1936b), Ruinen (1933), van Niel and Muller (1931) and van Niel (1932). See also Oren (2011).

The above examples are taken from hydrobiology. Oceanic biology and limnology, have a great advantage of dealing with homogeneous milieu or rather (as in stratified waters) with a different number of homogeneous milieus. Nearly all of our considerations pertain to these and similar environments, as the soil and the rock are highly heterogeneous and therefore difficult to characterise.

The laboratory milieu, when sufficiently characterised, enables us often to other specific organisms from an arbitrarily inoculum (garden soil, ditch mud, dust etc.). The milieu has a selective action. If we assume (Section 1) microbes to be omnipresent,[4] the definite question put by the composition of a well defined milieu will call for a definite answer in the form of the appearance of the vegetated (non-latent) stage of the organism resonating with this syndrome of milieu conditions. Various examples may be given. We must not forget however the laboratory milieu cannot enlighten as completely on the process of an organism. The potential milieu is perhaps not even known to the organism itself, in as much as conditions have never been varied enough to test its width.

3.2 Radiation

3.2.1 Introduction

Radiation has several important properties as a milieu factor. In the first place it is absorbed by all molecules and changed in heat. This means that the average molecular velocity is increased. Further it may import some of its energy to substances raising the energy potential of these substances. In both cases useful work may be performed in the first case (heat movement) water evaporates which may be condensed at higher elevations, where it can be used to drive a turbine. In the second case out of carbon dioxide and water, sugar may be found which kinetic energy has been changed into potential energy (quantum h V, in which V = frequency; h = Planck constant = 6.1×10^{-47}).

3.2.2 The sun as incandescent body

[Baas Becking inserted Fig. 3.4.]

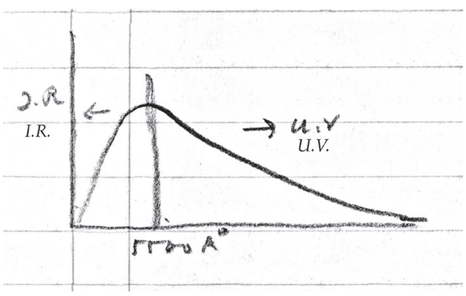


Figure 3.4 Intensity of solar spectrum. I.R. = Intensity Radiation; U.V. = Ultraviolet.

Nearly all the radiation we receive comes from the sun. This is an incandescent body of ±6500 °C, according to the wavelength of the most intense radiation at 5500 Å (Rayleigh's law $T = c\lambda^4$).

[Baas Becking further inserted Table 3.1 which compares the intensity of light during day and night.]

Table 3.1 Intensity of light during day and night.

From Smithsonian Tables (1918) values in metre candles	
Zenithal sunlight	103,324.0
Sky at end of twilight	355.0
Sky at sunset	4.3
Zenithal full moon	0.211

3.2.3 Radiation on earth

[Baas Becking left this section blank.]

3.2.4 Influence of latitude

[Baas Becking left this section blank.]

3.2.5 Influence of atmosphere

[Baas Becking left this section blank.]

3.2.6 Seasonal changes

Milankovicz[5]

3.2.7 Actual results

Here measurements with the Amalux,[6] as used at Leyden, and the solar meter are given. **a**. Zuyderzee 1935.[7] **b**. Somme 1937 and as many of the records I took in Australia. The effect of time of day, cloudiness *etc*.

3.2.8 Ultraviolet

Table 3.2 Relative energy related to wavelength. Data from Fabry and Buisson (1921).[8]

λ in Å	Relative energy	λ in Å	Relative energy	
3143	224 00 00	2936	11.00	The sharp cut off at λ < 3050 Å is, according to Luckiesch, due to the ozone in the outer atmosphere. The U.V. absorption of seawater is due according to Hulburt to magnesium salts.[9]
3104	151 00 00	2931	5.50	
3052	102 00 00	2922	2.20	
3922	27 00 00	2917	0.87	
2997	13 20 00	2912	0.38	
2963	132 00	2906	0.04	
2956	76 00			
2946	25 00	2898	0.02	

4 Baas Becking referred to the ubiquity of microbes that he discussed in Section 1.

5 Milankovitch Cycles describe the collective effects of changes in the earth's movements on its climate over thousands of years. The term is named for the Serbian geophysicist and astronomer Milanković (1879-1958).

6 Reference to a light meter Amalux of Metrawatt A.G. in Nürnberg. Metrawatt is now part of GMC Instruments, together with Gossen and Camille Bauer.

7 Baas Becking referred to the former inland sea Zuiderzee (or Zuyderzee), a shallow bay of the North Sea. in the northwest of the Netherlands, extending about 100 km inland and at most 50 km wide. In 1932 the majority of the Zuiderzee was closed off from the North Sea by the construction of the Afsluitdijk. The salt water inlet changed into a freshwater lake now called IJsselmeer (Lake IJssel) after the river that drains into it. In 1932 Baas Becking initiated the chemical research of the Ijsselmeer water that was done in the laboratory of the Rijksbureau voor Drinkwatervoorzienig by Dr. A. Massink (Baas Becking and Massink, 1934). Baas Becking presented the first results of the freshening of the Zuiderzee at the International Botanical Congress in Amsterdam in 1935 (Baas Becking, 1936).

8 The first accurate measurements of the amount of ozone in the atmosphere were made by Charles Fabry and Henri Buisson at Marseilles in 1920: *A Study of the Ultraviolet End of the Solar Spectrum.* See also Dobson (1968).

9 References to Luckiesch (1922) and to Hulburt (1928).

3.2.9 Infrared

[Baas Becking inserted Fig. 3.5.]

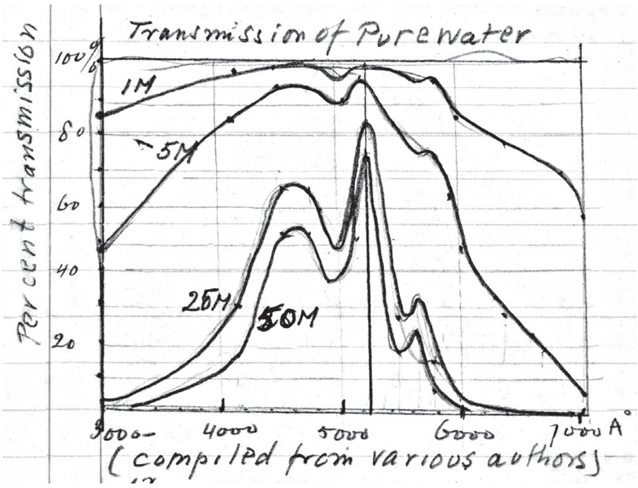


Figure 3.5 Percent transmission of pure water at 1 m, 5 m, 25 m and 50 m.

3.2.10 Radiation and water

[Baas Becking left this section blank.]

3.2.11 Radiation and the green leaf

[Baas Becking left this section blank.]

3.2.12 Radiation and evaporation

Evaporation in the Australian desert may amount to 30 ml/day, corresponding to an evaporation of 3.0 × 580 = 1,740 calories/cm^2 day, or taken, as 14 hours sunshine the solar constant, 2 cal/cm^2 minute, would be 100 % utilised! Usually this is not the case, however. In moderate latitudes we attain values ranging from 0.3 to 1.2 ml/day. Still to our surprise in a natural wet country like Holland evaporation seems to exceed precipitation (830 to 750 ml/yr.). Only our high soil-water level saves us from drought!

3.2.13 Summary and conclusions

[Baas Becking left this section blank.]

3.3 Temperature

[The following notes and references are written in ink and therefore probably entered into the manuscript before Baas Becking was in the Utrecht *Kriegswehrmachtgefängnis* [German army prison in wartime] in July and August 1944.]

Text box 3.1 – Baas Becking notes made prior to writing the manuscript

Protozoa. Glaser and Coria thermal springs Virginia. 34-36 °C, not 39-41 °C.[10]

Uyemura thermal water Japan. 30-51 °C, *Amoeba* sp., *Vahlkampfia limax*, *A. radiosa*, 36-40 °C, *A. verucosa*, *Chilodonella* sp., *Lionotus fasciola*, 30-56 °C, *Oxytricha fallax*.[11] Dallingen and Drysdale *Tetramitus rostratus* + 2 others, culture 16-70 °C.[12] Efimoff undercooling -9 °C, *Paramecium*, *Frontonia*, *Colpidium* persist, die quickly at –4 °C.[13]

Andrade, 1934, viscosity $\mu = Ae^{c/T}$, water does not follow below 60 °C, above 60 °C it follows this equation.[14]

3.3.1 Introduction

Not only that we have for vital processes a temperature minimum, optimum and maximum (v. Sachs),[15] but also in below optimal ranges especially biological reactions are usually highly influenced by temperature. There exist several excellent treatises on this matter. An older by Kanitz (1919) and a comparatively recent treatment by Bělehrádek (1938).[16] Usually an enormous anecdotal mass of data is brought together, but this would only come to confirm us about so. We restrict ourselves to the statement of a few generalities, pertinent to the concept of temperature as a factor of the external milieu.

3.3.2 The influence of experiments on chemical reactions

Chemical and biological processes both, it was known to Berthelot,[17] are influenced by temperature such that any 10 °C increase in temperature will double or triple the rate of the process. Van 't Hoff and Svante Arrhenius have given an empirical expression connecting the intensity of a process (reaction "velocity" with temperature) as;

$$I = A\ e^{-b/T}$$

or, at temperature T_1 and T_2;

$$I_1 = I_0\ e^{-\mu \frac{T_2 - T_1}{T_2 T_1}}$$

10 Reference to Glaser and Coria (1935).

11 Reference to Uyemura (1936). M. Uyemura working with samples from Japanese hot springs reported *Amoeba verrucosa*, *Chilodonella* sp., *Lionotus*, and *Paramecium caudatum* from temperatures between 36.0 °C and 40.0 °C; from the highest temperature range (30.0-50.0 °C) he recorded the hypotrichous ciliate *Oxytricha fallax*.

12 Reference to William Henry Dallinger (1842-1909) and John James Drysdale (1817-1892) collaborated on a series of experiments on flagellate protozoa that demonstrated that their spores could survive at temperatures above boiling point, thus undermining evidence for the spontaneous generation of life in supposedly sterile liquids. The results were published in the *Monthly Microscopical Journal* (1873-1876).

13 Reference to Efimoff (1924).

14 Reference to Andrade (1934).

15 Baas Becking referred to the work of Julius von Sachs (1832-1897), German botanist, from 1868 until his death Professor of Botany in the University of Würzburg. Among his extensive research in plant physiology, Sachs studied the influence of temperature on life processes (1860), especially the effects of freezing. He discovered the law of 'cardinal points', according to which each vital process has a minimum, an optimum, and a maximum temperature that are mutually related. In *Geobiologie* (1934) Baas Becking referred to his work in relation with the studies of van 't Hoff and Svante Arrhenius in the section on *Temperature*, p 64-69. Baas Becking was probably referring to J. von Sach's seminal monograph *Experimental-Physiologie der Pflanzen* [Experimental Physiology of Plants], published in 1865.

16 Reference to Aristides Kanitz (1877-?), Romanian chemist, who published several studies on the effect of temperature on living organisms. Baas Becking referred to Kanitz (1915).
Jan Bělehrádek (1896-1980). Baas Becking referred to his *Temperature and Living Matter* (1935).

17 Reference to Pierre Eugène Marcellin Berthelot (1827-1907), French chemist and politician, noted for the Thomsen-Berthelot principle of thermochemistry. He synthesised many organic compounds from inorganic substances.

The constant μ/2 is sometimes called the temperature characteristic and is thought to have the dimension of energy (W. Crozier). Unfortunately, the constant is not so very characteristic. Crozier (1924) has tried to find regularity in the μ of different biological reactions.[18] All in vain. In physiological reactions the Q_{10}, which is I_{t+10}/I_t = 2-3, decreases with increasing temperature.

3.3.3 The influence on chemical reactions: theory

According to Guldberg and Waage the reaction velocity should be proportional to the number of impacts, such as:[19]

a. ***Activation***. This is proportional to the average velocity of the molecules. It should be proportional to the absolute temperature. This would yield, between 10 and 20 °C a Q_{10} = 1.03 - 1.04! So, we often think that a certain group of molecules are *activated* by temperature (extend this?).

b. ***New analysis***, of Ohm's law I = E/R speaks about chemical intensity as a quotient of chemical potential and chemical resistance. Now, the potential is apparently not much influenced by temperature, but the resistance, the internal friction, the viscosity might be! Belehradek.

3.3.4 Influence on diffusion

On several physical processes, temperature has little influence. One of the best known is diffusion, both of gases under liquid or of solute in the solvent, the Q_{10} being 1.14. It has become a habit in physiology to ascribe processes with a low Q_{10} frequently to diffusion processes (see Section 4.1.6). Surface tension is another property, fast as density, refractive under that, varies but little with changing temperature.

3.3.5 Photochemical reactions

These are almost never influenced by temperature, beyond the effect expected from thermal agitation of the molecules in the milieu (Q_{10} = 1.04). There are, of course several weak processes. In the first place those connected with photosynthesis, further those connected with light perception, then the formation

20 In this section Baas Becking summarised different methods for determining the mechanical properties of the endoplasm.

In his 1953 manuscript Geobiology Baas Becking discussed Viscosity in Chapter IV, p. 227-230.

3.3.6 Viscosity methods[20]

a. ***Measurement of Brownian movement*** (Baas Becking, Pekarek). Micro method, based on equation of Einstein Smoluchovski; Baas Becking, Bakhuyzen and Hotelling (1925).[21]

$$\Delta^2 = \frac{RT}{N} \cdot \frac{\tau}{3\pi\mu\rho}$$

[Δ^2 = mean squared displacement; R = universal gas constant; T = temperature; μ = viscosity; ρ = radius particle; N = Avogadro constant; τ = time interval]

b. ***Stokes' law*** (Heilbrunn, Seifriz, Naber). Falling starter granules, in cell, moving iron particle in magnetic field, falling sphere, or ascending air bubble.[22]

$$F_d = 6\pi r \mu v$$

[Fd = Frictional force; r = radius of spherical object; v = flow velocity relative to the object; μ = viscosity]

c. ***Poiseuille's law (Oswald)***[23]

$$V = \frac{\pi}{8} \cdot \frac{p\, r^4 t}{\mu\, l}$$

[V = volume of the liquid; r = radius of vessel; t = time; p = change of pressure; μ = viscosity; l = length of vessel.]

Therefore yield from same tube of two liquids μ_1 and μ_2, $\mu_1 : \mu_2 = t_2 : t_1$ at constant temperature.

d. ***Couette method.*** Two concentric cylinders rotating one inside the other. Seems to be most satisfactory method although the falling bullet, under an angle of 80° is a close second. In the definitive section, topic should be extended.

18 Reference to Crozier (1924).

19 Reference to the law of mass action based on research performed from 1864 to 1879 by Cato M. Guldberg and Peter Waage. According to this law the rate of the chemical reaction is directly proportional to the product of the activities or concentrations of the reactants.

20 In this section Baas Becking summarised different methods for determining the mechanical properties of the endoplasm.
In his 1953 manuscript *Geobiology* Baas Becking discussed *Viscosity* in Chapter IV, p. 227-230.

21 Baas Becking summarised the method based on *Einstein's equation* for Brownian movement, relating the translation of a particle undergoing Brownian movement to the viscosity of the suspending fluid. The problem however is that the viscosity of the cytoplasm is much higher due to the great concentration of granular material, because protoplasm is not a pure liquid or a true solution. Moreover, the protoplasma is not homogeneous. Baas Becking referred to his own research: Baas Becking, van de Sande Bakhuyzen and Hotelling (1928).
Harold Hotelling (1895-1973) was associate Professor of Mathematics at Stanford University from 1927 until 1931. He is known for *Hotellings law*, *Hotelling's lemma*, and *Hotelling's rule* in economics and well as *Hotelling's T-squared distribution* in statistics.
Henriette Francisca Gerhards (1895-1966) was since 1925 the wife of H.L. van de Sande Bakhuysen who worked in the Stanford Food Research Institute. The research was part of her PhD study that she finished at Stanford in 1928. Baas Becking referred to Heilbrunn (1929) who wrote a critical review of "this interesting, but rather peculiar paper". See also Heilbrunn (1956); Heilbrunn (1958). Baas Becking was not impressed by Heilbrunn's critical remarks as is evident from a letter to F.A.F.C. Went from Pacific Grove December 9, 1929:
Some time ago, I was pleased to read an impossible critique of my viscosity study in *Protoplasma* by friend Heilbrunn, who is generally taken here as a querulant. I just didn't answer it. I know Millikan agrees with me and that is better. Moreover, a young lady from Philadelphia, Dr Evelyn Miller, is coming here in January to work on this topic! It is a proof that Heilbrunn didn't hurt me much.
Dr Evelyn Miller, not identified. See for H.L. Heilbrunn, Bereiter-Hahn, Anderson and Reif (1987).
Baas Becking also referred to J. Pekarek (University of Graz) who published in the 1930s several studies on viscosity measurements using the Brownian movement in *Protoplasma.*

22 Baas Becking summarised here the *centrifuge method*, in which a cell is put in a centrifugal field. The particles in the endoplasm move either in a centrifugal or a centripetal direction due to the density difference between the particles and the cytoplasmic matrix surrounding them. The velocity of a particle (V) is given by Stokes' law. Heilbrunn and his collaborators determined the viscosity of the endoplasm following the above principle.
Baas Becking further referred to the *magnetic particle method* where the movements of ferromagnetic particles in the magnetic field are influenced by the viscoelastic properties of the surrounding medium as well as the magnitude and gradient of the magnetic field and the magnetic susceptibility of the magnetic particles. Therefore, it is possible to determine viscoelasticity and yield stress of the protoplasm from the behaviour of a ferromagnetic particle in the protoplasm when a magnetic field is applied. Such an experiment was first carried out by Heilbrunn (1922), using slime mould plasmodia and then by Seifriz (1924).

23 A reference to the Oswald viscosimeter: according to Baas Becking *Geobiology* 1953, p. 228:" much used by biologists".

24 The reference to "v. Leeuwen and Baas Becking" referred to Geobiologie (1934) Chapter IV, Figure IV.1. There the viscosity of various types of water is shown as a function of temperature. The measurement of natural brine from Sand Springs Nevada, Oswald viscometer, referred to 'Oswald viscosimeter, van Leeuwen and B. Becking'. See also Section 3.5.5 Viscosity.

… of … [24] … in … as illustrated.]

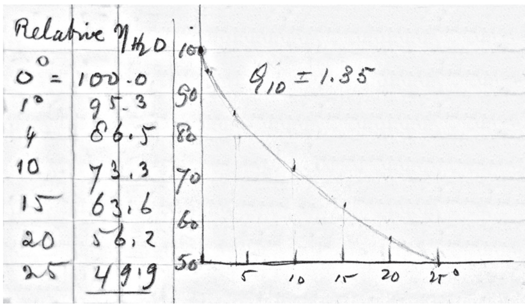


Figure 3.6 Viscosity of water as function of temperature (η = viscosity) (Baas Becking used the symbol μ instead of the more common μ).

Now Belehradek (1930)[25] called attention to the fact that, when dissolving substances in water, such as sugar, on mixing it with glycol, we may obtain temperature coefficients of any desired magnitude. Now viscosity is shearing force and had nothing whatsoever to do with chemical reaction. Still, it yields this very high Q_{10}. Belehradek looked for an explanation of the high temperature sensitivity of vital processes in the variable viscosity of the colloidal protoplasm.

3.3.8 Viscosity interpretation

Da Costa d'Andrade (1934) has succeeded to prove, from thermodynamic considerations the expression:[26]

$$\mu = Ae^{\frac{C}{T}}$$

in which A and C are constants … temperature and μ = dynamic viscosity]. …

$$Ae^{-\frac{(T_2 - T_1)}{T_2 T_1}}$$

and we see that this is the inverse of the Arrhenius expression. If a Nernst analogue:

$$I = E/R$$

applies and E is only a little influenced by temperature, one would account for I = f(T) becomes R, and the chemical resistance is highly influenced by T.

3.3.9 Physiological reaction

Generally only if temperature be a limiting factor we may see the temperature effect (see also Section 5.4).

3.3.10 Protoplasmic streaming

Hille Ris Lambers (1922) has shown that there exists a linear relation between temperature and velocity of protoplasmic steaming in *Nitella*.[27] Botteltier (1935) working with oat seedlings (coleoptiles) found no temperature influence below 17 °C.[28] Above that temperature the curve was linear. Baas Becking, Hotelling and van Sande Bakhuyzen have shown, by means of the measurement of particles in Brownian movement in *Spyrogyra* protoplasm, that micro currents exist and that their velocity is also a factor of temperature.[29]

3.3.11 Photosynthesis

Here v.d. Honert (1928) has done the classical work with the alga *Hormidium*.[30]

30 Taco Hajo van den Honert (1899-1959), substitute director in Buitenzorg during WWII in the absence of Baas Becking; successor of Baas Becking as Professor of Botany in Leiden (1945a). Baas Becking referred to van den Honert's Utrecht PhD thesis, Koolzuurassimilatie en Beperkende Factoren (1928), in which he published the results of his measurements of photosynthesis in Hormidium flaccidum.

3.3.12 Tropisms

[Baas Becking left this section blank.]

3.3.13 Respiration

[Baas Becking left this section blank.]

3.3.14 Development

[Baas Becking left this section blank.]

31 Reference to Von Kaleczinsky (1902) who suggested the use of stratified salt ponds as solar energy collectors. Baas Becking (1931a) referred to Von Kaleczinsky in his publication on Dunaliella viridis.

… limits of the temperature milieu

… s section blank.]

… haviour of milieu

(A. von Kaleczinsky).[31]

As brines have a lower specific heat than pure water, and as their vapour pressure, and consequently their evaporation intensity is less. They tend to heat up much more than freshwater. Temperature of 38 °C were observed by the author in Portugal in a saturated brine. In Bean Lake (Medve Lake) in Hungary, a layer of freshwater floating on the brine blankets it to such an extent that the brine heats up to more than 75 °C. The establishment of a bathing beach according

24 The reference to "v. Leeuwen and Baas Becking" referred to *Geobiologie* (1934) Chapter IV, Figure IV.1. There the viscosity of various types of water is shown as a function of temperature. The measurement of natural brine from Sand Springs Nevada, Oswald viscometer, referred to 'Oswald viscosimeter, van Leeuwen and B. Becking'. See also Section 3.5.5 *Viscosity*.

25 Reference to Bělehrádek (1930, p. 30)

26 See Baas Beckings reference to Edward Neveille da Costa Andrade (1887-1971) written in ink in Section 3.3, *Temperature*.

27 Reference to Hille Ris-Lambers (1926).

28 Reference to Bottelier (1935).

29 According to Allen and Roslansky (1959):

> Early estimates of "protoplasmic viscosity" were based on the unjustified and probably erroneous assumptions of homogeneity and Newtonian behaviour on the part of the cytoplasm. The use both of Stokes's Law with the centrifuge method and of Brownian motion to estimate viscosity depend on the correctness of these underlying assumptions. The notion of cytoplasmic homogeneity should have been dispelled by the painstaking study of Brownian motion in *Spirogyra* cytoplasm by Baas Becking, Bakhuyzen and Hotelling, who showed that "Brownian" movements of cytoplasmic inclusions were often non-random (*i.e.* directed) and limited, indicating that the cytoplasm is heterogeneous and cannot be characterised by a single viscosity coefficient.

30 Taco Hajo van den Honert (1899-1959), substitute director in Buitenzorg during WWII in the absence of Baas Becking; successor of Baas Becking as Professor of Botany in Leiden (1945a). Baas Becking referred to van den Honert's Utrecht PhD thesis, *Koolzuurassimilatie en Beperkende Factoren* (1928), in which he published the results of his measurements of photosynthesis in *Hormidium flaccidum*.

31 Reference to Von Kaleczinsky (1902) who suggested the use of stratified salt ponds as solar energy collectors. Baas Becking (1931a) referred to Von Kaleczinsky in his publication on *Dunaliella viridis*.

to v. Kaleczinsky, distributed the phenomenon. Still, it might be feasible, as he suggested, to use some such an arrangement for the accumulation of solar energy.

(This really belongs under *brines* in Section 3.13.5).

3.3.17 Summary and conclusions

[Baas Becking left this section blank.]

3.4 Other Physical Factors

3.4.1 Introduction

Apart from radiation and temperature the physical milieu has been very imperfectly studied. While aware of the fact that there is more between heaven and earth than is dreamt of in physiology, all sorts of physical causes have been ascribed to as many effects. Still, the result has been meagre. Promising would be the investigation of material or even (suspensions) and of high pressures (supposing that piezochemistry of aqueous systems were further developed).[32] Of the other physical factors, cosmic radiation, atmospheric electricity and the like, it seems best to relegate these to a box in which we stored our magic waste and our terrestrial rags.

3.4.2 Pressure

Water has a very low coefficient of compressibility although its space lattice (tridymite below 4 °C, quartdymite above 4 °C) does not exhibit the cases of closest packing. Pressure therefore, will but little change the aqueous phase of the living cell. Biological effects of pressure are mainly related to gases which, following the law of Henry decrease or increase their solubility in water proportional to the pressure. (Mountain sickness, diver's sickness, caisson disease). The law of Dubois-Reymond states that the rate of change in the intensity of a stimulus determines the intensity of the reaction.[33] This is also the case with pressure, where according to Henry's law, the solubility of gases is a function of the pressure and pressure changes may therefore, cause gases to escape from cells and thereby damage them (study on deep sea organisms). Shelford (Ecology) mentions a man's death from various species of flies after a sudden barometric depression previous to a storm.

3.4.3 Material waves

In the tropics a well known mode of fishing is by means of dynamite detonation under water. Quite large fishes are stunned, or even die by the material waves originated. Supersonic waves, originated by piezo quartz leave, when of sufficient amplitude, a lethal effect upon protozoa. Their disintegration may be observed immediately after application.

Other electromagnetic waves. The effect of ultraviolet is well known. Infrared (haute frequency) so often changes into heat, as water has intense absorption on the Infrared. Radium's deleterious effects of X-rays on cells is well known. Sublethal dose may in induce mutations. It has been claimed that ultra-shortwave radio may have a lethal effect on membranes.

3.4.4 Atmospheric electricity

(W. Pfeffer,[34] A. Stoppel,[35] A. Dezovica [?], T. Kleinhoonte,[36] F. Blackman).[37]

The periodic movement of leaves (as *Canavalia ensiformis*) from the periodic movement of leaf-inhabiting animals has raised the question behind this rhythm. Apparently not closely connected to a diurnal rhythm, might not be dictated by variations in atmosphere electricity, the gradient of which (± 100 volt/metre) may be easily measured by mean of an electroscope. The outcome of the very controversial matter has not led to a satisfactory general conclusion (Expand!)

3.4.5 Cosmic radiation

Well known are the investigations of Muller on mutation rates of *Drosophila*.[38] It seemed that the rate was less in deep mine pits where the Geiger counter registered a much lower increase of cosmic radiation then at the surface of the earth. It is also claimed (Bohr) that effects have been obtained on sea urchin eggs.

3.4.6 So called mitogenetic or Gurwitsch-radiation[39]

This should be augmented by all sorts of biological material, such as ground frog larvae, but especially spear frogs. It should be ultraviolet and have a profound effect on the number of cell divisions of a detector organism.[40] Unfortunately, a careful statistical investigation of the bacterial plate method of detection has shown that we have to relegate this theory to the realm of the "Wünschträume" (see further monograph of Rahn).[41]

3.5 Water

"*Eau, - - - tu es la vie*", de St. Exupéry, *Terre des Hommes.*

[Baas Becking inserted Table 3.3 in which the properties of water were summarised.]

32 Piezochemistry is the science dealing with the effect of pressure on chemical phenomena.

33 Baas Becking referred to Emil Heinrich du Bois-Reymond (1818-1896), German physician and physiologist. Du Bois-Reymond's law is a statement in physiology that a nerve is stimulated only by a change in electric current and not by a steady flow of electricity. Baas Becking applied the law in a broader perspective.

34 Refers to Pfeffer (1884) who studied chemotaxis of mosses and ferns. See for more recent review Simons (1981) and Section 7.4.3.

35 Refers to R. Stoppel (1915) who studied sleep movements of *Phaseolus multiflorus* and established a periodicity which she concluded was due to diurnal variation in atmospheric conductivity. She also showed that normal leaf movements are disturbed by completely insulating the plant from the earth and surrounding air.

36 Refers to Antonia Kleinhoonte (1929) and Kleinhoonte (1932). See also Section 4.2.5, Kleinhoonte investigated the leaf movement of jack bean, *Canavallia ensiformis*.

37 Refers to Blackman (1924) who conducted a meticulously controlled study of the growth of the coleoptile of individual barley seedlings treated with an electrical discharge. An increase in growth was observed.

38 Reference to Muller (1928).

39 Reference to Alexander Gavrilovich Gurwitsch (1874-1954), Russian and Soviet biologist, who contributed to the so called morphogenetic field theory in which 'mitogenetic rays' played a role. The theory is nowadays seen as 'pathological science'. According to the field theory the orientation and division of cells was random at local level but was rendered coherent by an overall field which obeyed the regular inverse square law, an enterprise that required extensive statistical analysis.

40 For a recent review of the effect of ultraviolet radiation on amphibians see Blaustein *et al.* (1998).

41 Reference to Rahn (1916a). According to the abstract, the paper "presents a discussion of the principle of dynamogenesis, the generation of power, force, or energy, especially muscular or nervous energy." In a following paper Rahn (1916b) the abstract reports: "The modern sensation as the psychical correlate of the process of stimulation of organs of sense might be traced from Plato, through Locke and Kant, to the fixing of the conception in the earlier experimental investigations of Weber and Fechner. The purpose of the present paper is briefly to trace this development, and then to point out some of the factors that are at the present time modifying or enriching our conception of the physical and physiological correlates of sensory consciousness."

Table 3.3 Properties of water.

1. Physical properties	Compressibility Cohesion Dielectric constant Heat consumption Specific heat Melting and boiling	Specific gravity Radiation Viscosity Surface tension
2. Chemical properties	Isotopes Ionisation Structure Theories of Barnes and Vouk.	Heat of formation of components Respiratory quotient
3. Physiological properties	Influence of temperature Water of metabolism The essence of metabolism Free and bound water Melting pressure and osmotic pressure	

3.5.1 Introduction

Water is a most unusual substance. While a substance like methane, M.W. = 16 or a substance like NH_3, M.W. = 17, have melting points far below zero (-70 to -80 °C) water, with its small molecular M.W. = 18, is a liquid at average terrestrial temperature. In nearly all of its physical properties it shows the same extreme character, its dielectric constant, its ionisation, its dipole character, its specific heat. We should not be amazed to find authors like the Rev. Whewell, who in his *Bridgewater Treatises* wrote paeans on this topic in order to show that this substance, the regulator of temperature and the regulator of life upon this planet, is placed here by special providence to enable us to enjoy the earth.[42] A little more modesty allows us to see that life, as we know it, is counterpart of the water and the question whether water is here because of life or life is here because of water seems theological rather than scientific. We shall revert to this problem in Section 3 and in Section 5.

3.5.2 Physical properties

MP and BP, vapour kinetics. The whole range between zero and 100 °C is available for life. In this range most physical and chemical properties change gradually. MP and BP are influenced by dissolved substances, according to rules given by van 't Hoff. The rather high vapour pressure makes for effective use of absorbed radiation.

3.5.3 Physical properties: specific gravity

Spring and fall mixing of freshwater masses (Fig. 3.7). Pure water has an optimal density at 3.98 °C. Freshwater of this temperature is therefore the heaviest, and it will mix if the depth of a natural body of water be great, the deepest layer (hypolimnion) shall have this temperature. Later we shall revert to this phenomenon, when natural waters are described. In seawater (3.5 % salts), the temperature of maximal density is below zero and even below the freezing point of seawater, so that this factor cannot play a role in the vertical mixing. As in ocean water also salinity exerts its influence, vertical as well as horizontal currents may be predicted, salinity and temperature, being known, from the so called Bjerkness-theorem.[43] Discussion of which would lead us too far.

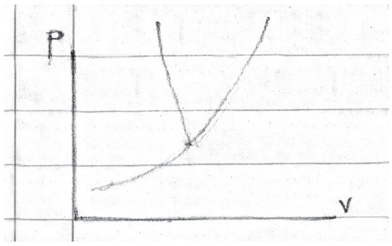


Figure 3.7 Spring and fall mixing of freshwater masses.

3.5.4 Radiation

Water has usually a high absorption in the infrared, with distant bands (plate after Ellis). Aschkinass (1895) has determined the absorption coefficients for various wavelengths.[44] The absorption decreases towards the blue end of the spectrum, the "blueness" of water is due to this fact and also connected with light dispersion (Rayleigh phenomenon), which is the cause of the blueness of the sea. Water is fairly transparent to ultraviolet rays.[45] The opacity for these wavelengths in seawater is caused, according to Hulburt, by the magnesium salts present.[46]

3.5.5 Viscosity

μ = 0.01 poises at room temperature, with a temperature coefficient of 1.4. Winter and summer viscosity are, therefore quite different, a fact which has an important bearing upon the flotation power of plankton (Woltereck, Kizaki, *Daphnia*).[47] The temperature coefficient increases with the amount and the nature of dissolved substances (Baas Becking, v. Leeuwen, Belehradek).[48] A solution of 1 N cane sugar has

42 Baas Becking referred to Rev. William Whewell (1794-1866), an english Professor of Mineralogy (1828) and from 1838 Professor of Moral Theology and Casuistical Divinity in Cambridge. His *Astronomy and General Physics considered with Reference to Natural Theology* (1833) was published as one of the eight Bridgewater Treatises as his contribution to the contemporary debate over the applicability of teleology to scientific questions. Henderson (1913, p. 3-8) was Baas Becking's source for Whewell. Baas Becking regularly referred to Whewell in his unpublished manuscripts. On March 2, 1928 in his notebook with excerpts from his lecture course at Utrecht University, he quoted from Whewell's *Astronomy*:

> It has been shown in the preceding chapters that a great number of quantities and laws appear to have been *selected* in the construction of the universe; and that by the adjustment to each other of the magnitudes and laws thus selected, the constitution of the world is what we find it, and is fitted for the support of the vegetables and animals in a manner in which it could not have been, if the properties and quantities of the elements had been different from what they are.

Source: Handwritten manuscript AAS Basser Library Ms. 043 nr 159, p. 108.

43 See for Bjerkness circulation theorem Chapter I.2.3.

44 'Ellis' not identified. Reference to Aschkinass (1895). Emil Aschkinass (1873-1909), Privatdozent Universität Berlin (1906-1909), who translated Ernest Rutherford's *Radioactivity* in German in 1907. Aschkinass became a victim of the lethal effects of atomic radiation experiments in which he was involved, passing away in 1909 from overexposure to gamma rays.

45 See for review Buiteveld, Hakvoort and M. Donze (1994).

46 Baas Becking referred to Hulburt (1928).

47 Reference to Woltereck (1913); Woltereck (1930), here Woltereck referred to Kikuchi (1928).

48 In *Geobiologie* (1934) Chapter IV, Figure IV.1 of the viscosity of various types of water, shown as a function of temperature, there is a measurement of natural brine, saturates Sand Springs Nevada, Oswald viscometer with reference to van Leeuwen and B. Becking.

already very high aqueous effluent. S... may result. The bearing of this phenom... effects is discussed elsewhere, Correns...

54 Reference to the 'active osmotic water absorption' theory by William Ringrose Gelston "Billie" Atkins (1884-1959), Irish chemist. He co-authored 10 papers with the plant physiologist Henry Horation Dixon (1869-1953) on osmotic pressure during his stay at the Botany group of Trinity College, Dublin (1906-1921). The root cells behave as an ideal osmotic pressure system through which water moves up from the soil solution to the root xylem.

See Atkins (1916), Dixon and Atkins (1915), Dixon and Atkins (1916).

3.5.6 Surface tension

(2 ergs/cm2, an extreme value again). ... is lowered by traces of dissolved su... by lipophilic substances. Czapek has ... permeability on the fact that many permeating substances are able to lower the surface tension of water.[50] Substances, which lower the surface tension, accumulate at interfaces, and so the lipophilic outer layer of liquid protoplasm may be accounted for. After diatom epidemics the surface tension of the ocean may be lowered and foam formation much favoured. After spring and autumn blooms of diatoms the phenomenon may be regularly observed.

3.5.7 Dielectric constant

$\varepsilon = 81$ is by far the highest known, ... with $\varepsilon = 67$. Keller has elaborated ... which takes into account changes ... According to the law of Lorentz-L... to the refractive angle which in ... $\varepsilon p^{25} = 1.334$, only deuterium oxid...

55 According to Rob Raiswell the reaction should probably be CaC2 + 2H2O = C2H2 + Ca(OH)2

Saponification is a process that involves conversion of fat or oil into soap and alcohol by the action of heat in the presence of aqueous alkali (e.g., NaOH). Soaps are salts of fatty acids whereas fatty acids are saturated monocarboxylic acids that have long carbon chains (at least 10) e.g., CH3 (CH2)14COOH.

3.5.8 Thermal properties

Water has a very high heat of fusion (80 cal) and a remarkably high heat of evaporation (580 cal at room temperature). This last value is the cause of the heat regulation due, on this planet, to water evaporation. The high specific heat, which does not fit Dulong and Petit's rule,[52] makes water an ideal heat accumulator, that accumulates and thermostats in one the 2/9 of the earth's surface which are covered with water, actually guards against overheating and too rapid cooling. Apart from volcanic action the highest temperature on record in aqueous milieu is [*ca.* 35 °C] (Persian Gulf) on land 84.6 °C in the African desert. The author measured 31 °C in the Pacific near Corinto Nicaragua July 1928,[53] and 62 °C on a black sand of Verlaten Eiland, near Krakatou, Sunda Strait, October 1939.

3.5.9 Cohesion

..., probably due to the ...mpermeable molecules ...ncy to form chains (see ...nn of several hundred ... of Atkins of the water ...sion theory, makes use ... which evaporate at the top and are replenished from below.[54] The cohesion process also accounts for the ease with which water, with only a little colloid (0.2 % agar) will form a solid substance.

The impermeability is very low, although the lattice structure does not represent closest packing.

3.5.10 Chemical properties

Water reacts with several metals, forming the molecule of ...

... $M(OH)_2 + H_2$

...oth inorganic and organic ...luded in sufficiently water- ...ns acetylene:

... $2CaO + CH\text{-}CH$

It is able to saponify ester:[55]

$$CH_3COOC_2H_5 + H_2O = CH_3COOH + C_2H_5OH$$

An enormous range of substances, polar and non-polar, are soluble in water. Many molecules orient themselves in water (spreading). Water is also a universal catalyst.

3.5.11 The ionisation

The ionic product of water Kn is, at room temperature 7×10^{-14} (Kohlrausch), influenced by the temperature. The hydrogen ion H+ is nowadays conceived as hydrated OH_3^+. Neutral point exists when

$$[H^+] = [OH^-] = \sqrt{7 \times 10^{-14}} = 10^{-7} - \log [H^+]$$

and is called pH. pH at neutral point is therefore 7.0. The oxygen ion O^{2-}, as supposed by Nernst, may exist although the second dissociation constant of water will be exceedingly small.

---

49 Reference to Correns (1939, p. 119).

50 Friedrich Johann Franz Czapek (1868-1921), Polish botanist developed a growth medium for propagating fungi and other organisms.

51 Baas Becking referred to Keller (1925). The electrical factor in vital staining has been stressed particularly by Keller. He proposed to discontinue the division of dyes into acid and basic dyes, and to distinguish them according to their migration in the electric field, as cathodal or anodal dyes.
In the University of Arizona Library there is a master thesis By Harriet Mabelle Fogg (1930), *The Physiological Activity of the Root as Indicated by Vital Staining*, in which she acknowledges on the first page:

> Dr. H.L. van de Sande Bakhuyzen for his suggestion of a problem which has proved to be very interesting.
> H.L. van de Sande Bakhuysen ("Bakkie") came to Stanford in 1925 as a colleague of Baas Becking. In 1928 he obtained a research place in the University of Arizona. He must have communicated with Baas Becking about his interest in vital staining and Keller's study.

52 Reference to the Dulong-Petit law, a thermodynamic law proposed by French physicists Pierre Louis Dulong and Alexis Thérèse Petit, states the classical expression for the molar heat capacity of certain chemical elements.

53 On board of the M.S Annie Johnson near the Bay of Monterey, Baas Becking wrote to F.A.F.C. Went (June 19, 1928):
Here in Corinto I also had the great surprise of the trip! One morning when DrYates [from Deli] and I strolled along the beach ("Guppy's whole book" is on the beach) we came to a strip about 500 metres long where the waves were coloured greenish brown. The beach was covered with a brownish mass! Immediately I thought of collecting my diatoms and a bit of sand in a matchbox, so I sunk on means to obtain a microscope […] To my great surprise, the diatom was again *Aulacodiscus kittonii*. […] Strange that this organism also occurs in masses in tropical seas! […] This find was worth the very long journey. [Translated from the Dutch AJPR]
Baas Becking collection, Library Boerhaave Museum Leiden. See for "Guppy" Section 4.3.7a.

54 Reference to the 'active osmotic water absorption' theory by William Ringrose Gelston "Billie" Atkins (1884-1959), Irish chemist. He co-authored 10 papers with the plant physiologist Henry Horation Dixon (1869-1953) on osmotic pressure during his stay at the Botany group of Trinity College, Dublin (1906-1921). The root cells behave as an ideal osmotic pressure system through which water moves up from the soil solution to the root xylem.
See Atkins (1916), Dixon and Atkins (1915), Dixon and Atkins (1916).

55 According to Rob Raiswell the reaction should probably be $CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$
Saponification is a process that involves conversion of fat or oil into soap and alcohol by the action of heat in the presence of aqueous alkali (*e.g.*, NaOH). Soaps are salts of fatty acids whereas fatty acids are saturated monocarboxylic acids that have long carbon chains (at least 10) *e.g.*, $CH_3(CH_2)_{14}COOH$.

3.5.12 The isotopes

Deuterium, M.W. = 2, was discovered in 1935 by Urey.[56] D_2O is a liquid very much like water, showing even anomalous expansion and maximum density at 3.5 °C. It solidifies at +3 °C, it boils at 101 °C, its refractive index is, for a liquid, is exceedingly low $N_d^{15} = 1.29$. D_2O was originally prepared from the liquid in a long used electrolytic bath, it was, therefore, originally contaminated with nickel. D_2O is present 1:5000 in natural waters. It does not accumulate in desert waters as Prof. P. Cohen had the kindness to analyse the brine of Searles Lake, Nevada[57] which, however, showed no increase! Physiological processes seem on the whole, retarded in D_2O, although the effect is often slight. More important is the use of D_2O in the Harvey technique of marked atoms to establish the role of water in physiological processes.[58] This technique has contributed much to elucidate the fact that the quintessence of metabolisation might well be the reaction

$$2\ H_2O \rightleftarrows O2 + 2\ H_2 \text{ or } H_2\ O \rightleftarrows O + 2H.$$

It has been said metaphorically that hydrogen is the fuel of living things. To the author this dictum is more than a metaphor.

3.5.13 The structure

Bernal and Fowler (1933) have shown that ice, at a too low temperature, and water below the point of maximum density, has a lattice structure much like tridymite (SiO_2).[59] Above 4 °C, up to ± 200 °C, the lattice structure is closer, like quartzite, while the crystalline structure is reached between 200 °C and the critical point at 314 °C. There is evidence of chain formation (Fig. 3.8), but not so far as to warrant older assumptions of Armstrong (1908) according to which there should exist a tri-di-and mono- hybrid, the former in ice, the latter in steam.[60] Water is, of course, a dipole $\mu = 18 \times 10^{-18}$. The distances in the lattice are 2.9×10^{-8}Å, 1.4×10^{-8} Å, and the valency angle 104-106°.

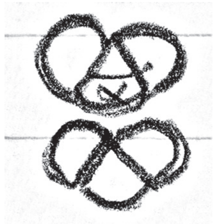


Figure 3.8 Chain formation of water. After Armstrong (1908).

3.5.14 Theories of Barnes

Barnes, father and son,[61] and Vouk have claimed that water which has been recently obtained from ice has other properties then water obtained from steam.[62] The former exerts a beneficial effect upon organisms. The latter shows a deleterious influence. Repetition of their experiments with the algae *Spirogira*, and careful viscosity measurements of water of known previous history have convinced me that there is such effect. Vouk and recently Radermacher claim that water, autoclaved at a high temperature ("fervorised water") has a beneficial effect, as compared to "non-fervorised" water.[63] Boezeman has repeated the experiments in my laboratory with positive results. I am unable to account for the curious phenomenon, which is not due to trace elements, having made use of quartz throughout.

3.5.15 Heat of formation of organic compounds of acid and bases[64]

The heat of formation of water, from the elements, amounts to 56,500 calories. The heat of formation from the ions is 28,000 cal. This is also the heat of neutralisation, when a base is titrated by an acid

$$NaOH + HCl = NaCl + H_2O$$

or

$$Na^+ + H^+ + OH^- + Cl^-$$

According to the values given by L. Pauling for heat of formation of organic radicals the heat of formation of an organic compound does not change if its H and the number of its H and O atoms be increased or decreased in a ratio 2:1 as in H_2O (see Plate 3.1).[65] From this plate it may be seen which processes require energy, and by which energy is liberated.

See also Figure 6.5, Figure 6.6 and Table 6.2.

56 Baas Becking referred to Harold Clayton Urey (1893-1981), American physical chemist, who was awarded the Nobel Prize in Chemistry in 1934 for "his discovery of heavy hydrogen" in 1932. In 1959 Baas Becking was irritated that Urey did not believe in the Franklin ammonia chemistry. See Section 2.5.2, *Ammonia chemistry* and note.

57 Professor P. Cohen not identified.

58 Baas Becking possibly referred to Rudolf Schoenheimer's *Harvey Lecture*, January 21, 1937, *The Investigation of Intermediary Metabolism with the aid of Heavy Hydrogen*.

59 Reference to Fowler and Bernal (1933).

60 Refers to H.E. Armstrong (1908). Baas Becking discussed Amstrong's view of water as a mixture of three polymers in Chapter V of *Geobiologie* (1934), section *Water* (p. 45, English edition, 2016).

61 Baas Becking also discussed the theory of Barnes in *Geobiologie* (1934, p. 45-46).
References: Barnes (1932), Lloyd and Barnes (1932), Barnes and Jahn (1934 Barnes and Larsen (1935).

62 Reference to Vouk (1929).

63 Reference to Radermacher, Klas and Vouk (1940). By fervorisation the authors "understood the heating of plant nutrient-substrate to a high temperature". See also Radermacher and Klas (1950). In the 1953 manuscript of *Geobiology* (p. 252) Baas Becking referred to the experiments:

> It has been known for a long time that the heating of soil or of culture solutions may cause a remarkable increase in yield in plants grown in these solutions, as against controls. In the case of glucose containing solutions, the effect may be partly ascribed to the formation of dienoles, such as reductone. But Radermacher and Klas (1940) showed that if only the water were heated to 137 °C "(fervorised)" previous to the preparation of a mineral culture solution (von der Crone), increase of yield over the control could be demonstrated in various instances. As obvious sources of errors, like the shift in oxygen solubility with decreasing temperature, could be ruled out the effect seems to be a real one.

This work done in Zagreb, Yugoslavia, before the war caused much surprise. It was repeated at the Leyden Laboratory with positive results. The cause of this phenomenon is obscure. The effect may be enhanced when the mineral nutrient solution is fervorised as such.
Since the 1950s no reports on fervorisation were published. It seems that fervorisation belongs to the same class of phenomena as Lysenko's 'vernalisation' see Section 5.2.3.

64 See Baas Becking (1947b) for a description of the equilateral triangular plots. See also notes in Section 3.10, $CH_2 = CH_2$.

65 Reference to Linus Pauling (1901-1994), American chemist, biochemist, chemical engineer, peace activist, winner of Nobel Prize (Chemistry, 1954; Peace, 1962), Pauling (1939). See also a reference to Pauling, Section 7.8.9, Figure and Table 6.2.

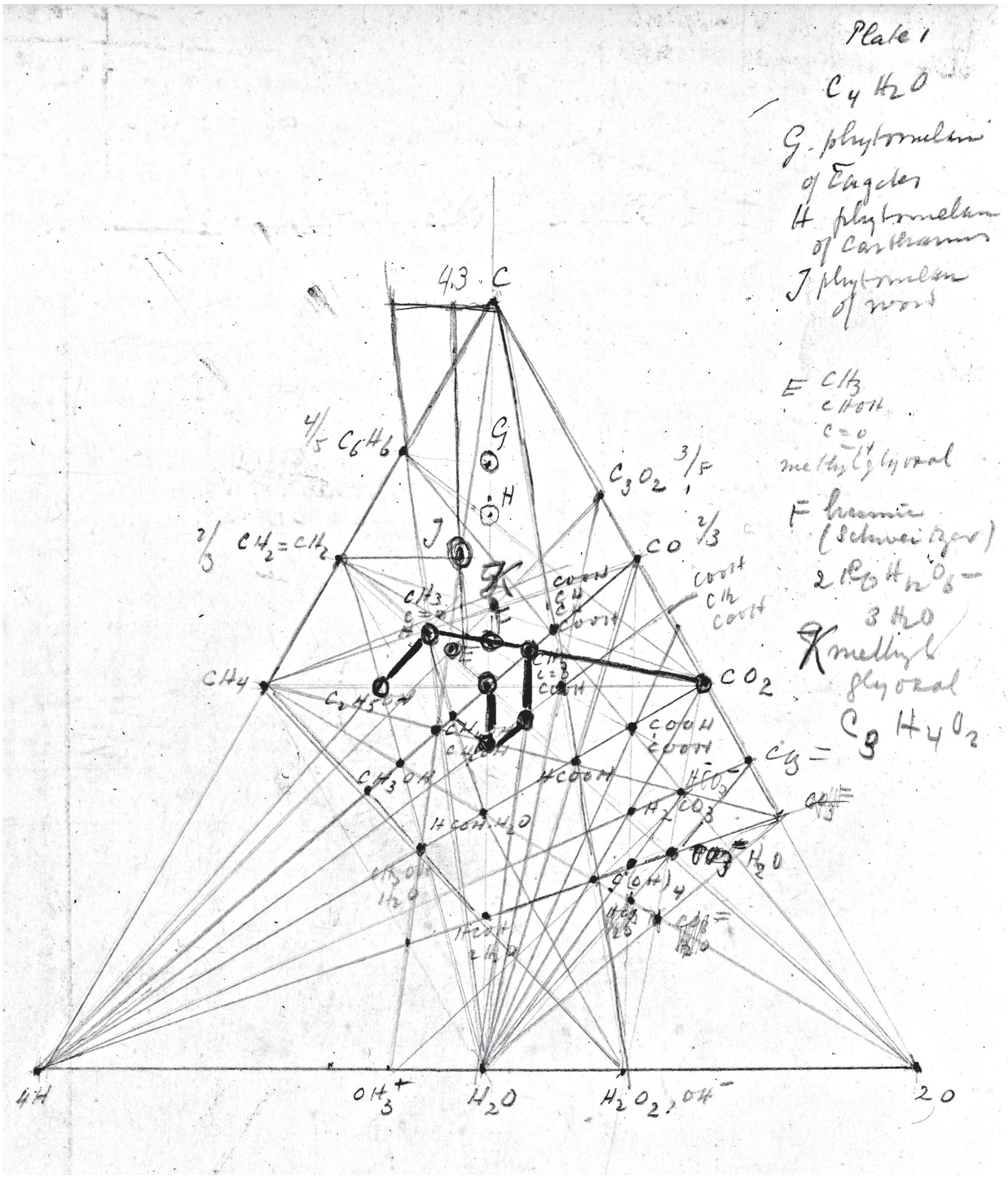


Plate 3.1 Equilateral triangular plot with compounds of C – 4H – 2O, showing the molecular composition of phytomelan, methylglyoxal and glucose. The black lines show changes in the composition of organic matter by decarboxylation and dehydration. The letters refer to: G. Phytomelan of *Tagetes*; H. Phytomelan of *Carthamus*; J. Phytomelan of wood; E. $CH_3C(O)CHO$ Methylglyoxal; F. Humic (Schweizer) 2 $C_6H_{12}O_6$ - 3 H_2O [Baas Becking referred to Schweizer's reagent which was used to extract cellulose from natural cellulose sources such as humic material]. The formula refers to caramelisation of glucose; K. Methylglyoxal $C_3H_4O_2$.

3.5.16 The respiratory quotient

Complete combustion of an organic compound

$$C_aH_bO_c + xO_2 = aCO_2 + \frac{b}{2H_2O}$$

yields for the respiratory quotient RQ = a/x. Now:

$$c + 2x = \frac{b}{2} \text{ or } x = \frac{b}{4} - \frac{c}{2} \text{ or } RQ = \frac{4a}{b - 2c}$$

From this it follows, that addition, or subtraction of H_2O + a molecules will not change the RQ of the compound. From the rule found for the heat of formation of organic compounds we may derive directly H × RQ = heat = 120,000 cal/at c (see Plate 3.2). In incomplete combustion or in more complex reactions the relation, however, does not hold.

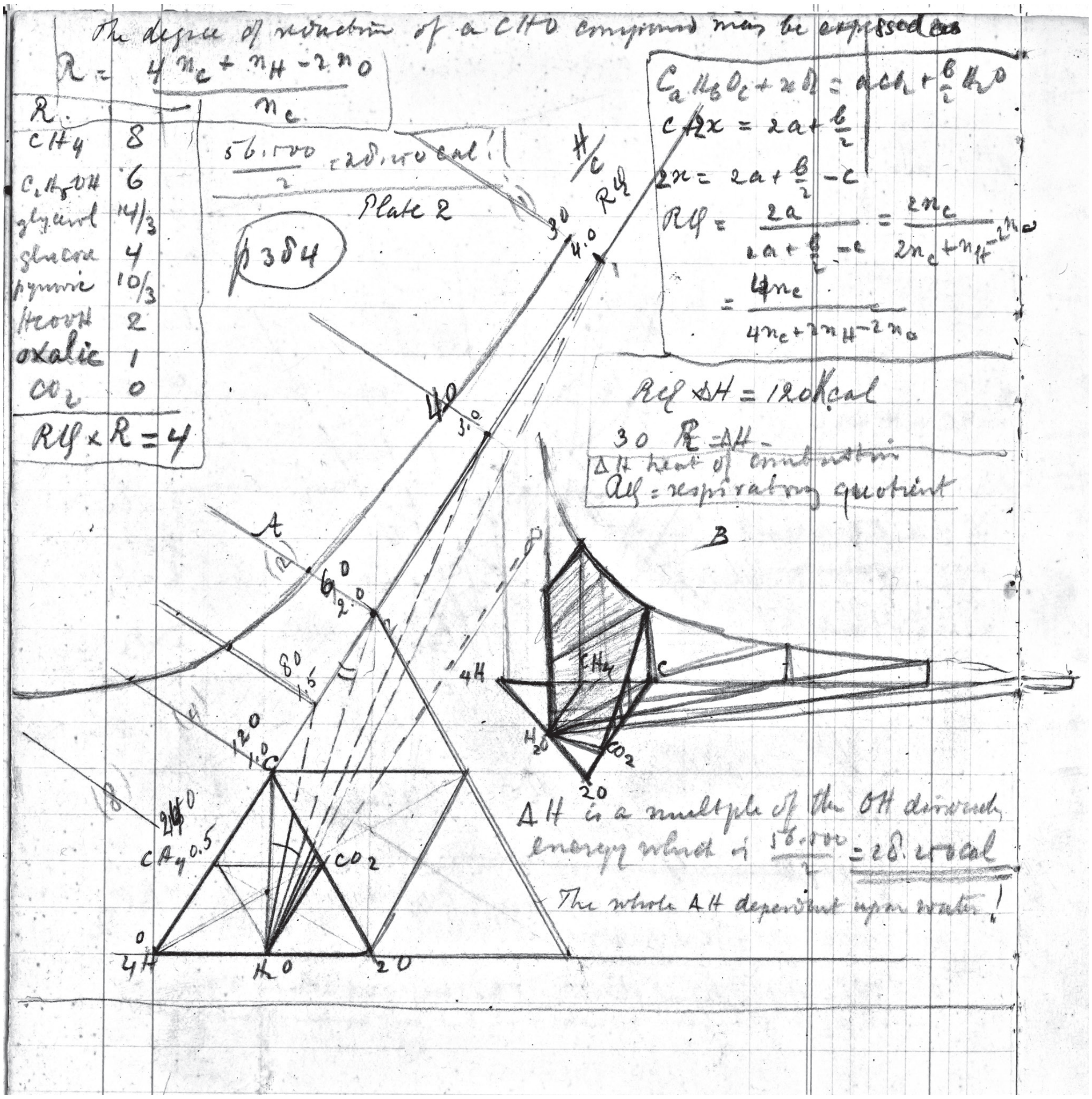


Plate 3.2 Equilateral triangular plot with compounds of C – 4H – 2O, relating changes in the composition of organic matter to heat combustion and respiratory quotient. See Baas Becking (1947b) for explanation.

[The transcript of the notes in the plate reads as follows:]

$$\frac{56{,}000}{2} = 28{,}000 \text{ cal!}$$

R[eduction state]	
CH_4	8
C_2H_5OH	6
Glycerol	14/3
Glucose	4
Pyrinic	10/3
HCOOH	2
Oxalic	1
CO_2	0
RQ × R = 4	

The degree of reduction of a CHO compound may be expressed as

$$\text{R[eduction] state} = \frac{4n_C + n_H - 2n_O}{n_C}$$

$$C_aH_bO_c + xO_2 = aCO_2 + \frac{b}{2}H_2O$$

$$c + 2x = 2a + \frac{b}{2}$$

$$2x = 2a + \frac{b}{2}$$

$$RQ = \frac{2a}{2a + \frac{b}{2} - c} = \frac{2n_C}{2n_C + n_H - 2n_O} = \frac{4n_C}{4n_C + 2n_H - 2n_O}$$

RQ × ΔH = 120 kcal
30 R = ΔH
ΔH = heat of combustion
RQ = respiratory quotient
ΔH is a multiple of the OH dissociation energy which is 56,000/2 = 18,000 cal.
The whole ΔH is dependent upon water!

3.5.17 Physiological properties: temperature

The impact of the water molecules in thermal agitation may cause small objects ($\phi < 10\rho$) to perform irregular, microscopically observable, motions (Brownian movement). Here the average deviation square of such a particle in time τ,

$$\Delta^2 = \frac{RT}{N} \cdot \frac{\tau}{3\pi\mu\rho}$$

In which Δ^2 = mean squared displacement; R = universal gas constant; T = temperature; μ = viscosity of the milieu; ρ = radius particle; N = Avogadro constant; τ = time interval.

By means of this equation the author, with v.d. Sande Bakhuyzen, and later Pekarek, have shown that protoplasm, in certain instances, behaves almost like a dilute aqueous solution. See also Section 3.3.6.[66]

3.5.18 Water of metabolism

It has been shown by Beyer [?] that the water content of the clothes moth and of the wax moth is entirely derived from metabolic water, that is water derived from dehydrogenation and oxidation of organic substances, *e.g.*, when sugar is metabolised.

$$C_6H_{12}O_8 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O.$$[67]

It is safe to assume that there are many organisms, which provide themselves with water in this way, for example the petroleum fly *Psilopa petrolei* (Thorpe, 1930).[68] Furthermore it seems safe to infer that part of the water present in every organism may be considered as metabolic water.

3.5.19 The essence of metabolism

We recall an old experiment of Wieland a good model of catabolism;[69] the oxidation of CO – CO_2 in aqueous solution + Al catalyst.

We find:

$$CO + H_2O = HCOOH$$

$$HCOOH = H_2 + CO_2$$

$$H_2 + X = H_2X$$

$$(H_2 + O) = (H_2O).$$

We find a hydration, a hydrogen generation and a hydrogen acceptance, the latter usually as the formation of water. As such we suggest conceive the last act of metabolism, is acceptance of metabolic hydrogen by oxygen. Inversely, we might consider photosynthesis as a photolysis of water; the hydrogen evolved being accepted by carbon dioxide to form organic compound: *photolysis and formation of water lie at the base of all metabolism* (heat of formation from the elements 56,500 calories).

3.5.20 Swelling pressure (osmotic pressure)

Osmotic phenomena may generate pressures of several hundreds of atmospheres, due to the one sided impact of dissolved particles delivered upon a membrane, the amount of energy liberated doing swelling of colloids, however, is such that the swelling pressure is measured by thousands of atmospheres! (colloid pressure, Energia, Graham).[70] As shall be argued later more extensively, all water intake by living things is regulated by one or both effects. The author, in a lecture for the Nat. Academy at San Francisco in 1929 has developed a picture of both pressures (Fig. 3.9).[71]

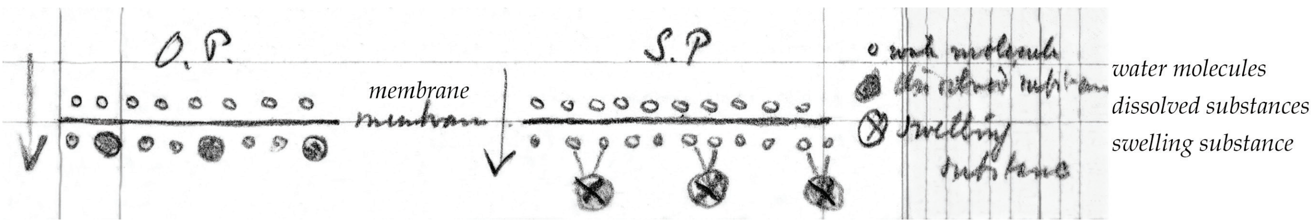


Figure 3.9 *Osmotic pressure (O.P.) and swelling pressure (S.P.).* Symbols: o water molecules; • dissolved substances; ⊗ swelling substance.

66 Refers to Baas Becking, van de Sande Bakhuyzen and Hotelling (1928); Pekarek (1930). Pekarek refined his observations during the 1930s with several 'Mitteilunge' in *Protoplasma*. See for Henriëtte van de Sande Bakhuyzen-Gerhards also Section 3.3.6.

67 See also Section 4.4.4 where Baas Becking referred to the unidentified author 'Beyer'.

68 Present name *Helaeomyia petrolei* (Coquillett, 1899). Baas Becking referred to Thorpe (1930). In the 1953 manuscript of *Geobiology* (p. 244-245), Baas Becking referred to Thorpe:

> Organisms living under conditions of drought, whether exposed to the atmosphere, or in non-aqueous solutions, have to subsist on metabolic water. The best known cases are the flour moth and the clothes moth, although the occurrence of the curious fly *Psilopa petrolei* described by Thorpe (1930) from oil wells, (the larvae of which feed on "oil" microbes) suggest that either the larvae of the microbes should make use of metabolic water. Here is another field for the use of isotopes.

See also Section 4.4.4 where the author of the clothes and wax moth is mentioned as Beyer (not identified).

69 Heinrich Otto Wieland (1877-1957), German chemist who won the Nobel Prize in Chemistry in 1927. Baas Becking referred to Wieland's research on the oxidation of acetic acid by yeast cells.

70 The reference is to Thomas Graham (1805-1869), Scottish chemist, pioneer in dialysis and diffusion of gasses, founder of colloidal chemistry. According to Graham the special nature of colloids can be traced back to ENERGIA, the source of force in vital phenomena. Colloids are presented as the likely source of biological activity and hence the vital source of life.
See Graham (1861) and Ede (2007).

71 Baas Becking probably gave his lecture to the California Academy of Sciences in San Francisco. The text of the lecture was not retraced.

3.5.21 *Free and bound water*[72]

Gortner has in the last decennia developed the concept of bound water which is, essentially similar to that depicted under swelling pressure.[73] It is not, or is only partially, available for osmotic and chemical action. It may be determined by the expected and observed expansion at freezing of solutions, expected and observed contraction at the fusion of solutions, action on cobalt salts or measurement of freezing parts or of vapour pressures. In plant cells the amount of bound water shows a relation to drought and to frost resistance (Newton, Scarth and co-writers).[74] By measuring the volume of a plant vacuole in solutions of varying hypertonicity the deviation of the Boyle's law PV = CT measures the bound water as a van der Waals correction P (V-b) = CT. This may be the only reliable way to measure bound water, which, according to some authors, is in no way different from free water.

3.5.22 *Summary and conclusions*

This description of the properties of water is far from complete. Moreover, the advancement of science adds new data almost every year. We did not speak of the role of water in electrochemistry, in colloid chemistry. We did not mention the various forms of ice. Raman spectra and X-ray data were also omitted. Still the picture given will suffice to show the extraordinary, and complicated nature of this most marvellous of terrestrial substances. If any substance on earth is the counter mould, the resonator, the very core of life, it is water. Paramount not only as a biological substance, but also as the central compound of chemistry, and one of the most important factors in geology, it is the veritable carrier of things geobiological and geochemical. Few, if any substances (perhaps apart from liquid ammonia) could, at any place in the cosmos, fulfil a comparable role.

3.6 Gases

3.6.1 *Introduction*

The gases that are dissolved in water may be roughly divided into two groups, which differ greatly as to their solubility. The first group, comprising carbon dioxide, ammonia and hydrogen sulphide, react with the water and are, consequently more soluble in water, while the other group, represented by oxygen, nitrogen, hydrogen do not associate themselves chemically with the water. Both groups are, however, subject to Henry's law: the amount of the gas dissolved is proportional to the pressure of that gas, equilibria however, are very slow to establish themselves. Supersaturation with oxygen of 300 % may scarcely occur, while it takes 24 hours mechanical shaking to bring water into equilibrium with a gas as CO_2. The swiftness with which equilibria are established has an important bearing on hydrobiology, as a water may show something of its history by the composition of its gases.

3.6.2 *Highly soluble gases: CO_2*

[Baas Becking inserted Fig. 3.10, ratio of carbonic acid and bicarbonate and carbonate as a function of the various acidity levels.][75]

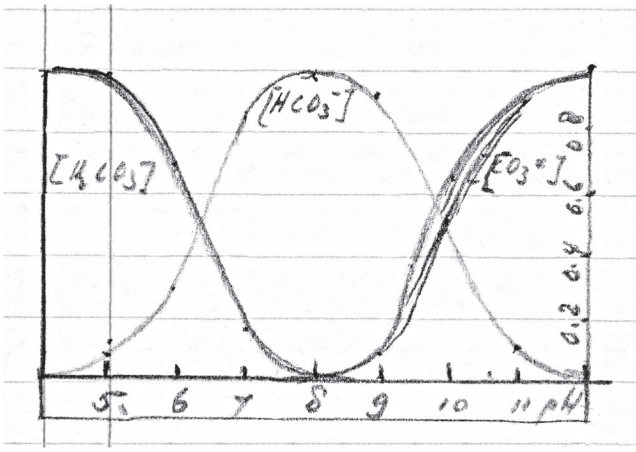


Figure 3.10 Ratio of carbonic acid and bicarbonate and carbonate as a function of the various acidity levels.

Part of CO_2 dissolved on water from [H_2CO_3] (see also Section 4.3.2). This H_2CO_3 is dissociated

$$k_1 = \frac{[H^+][HCO_3^-]}{[H_2CO_3]} = 4 \times 10^{-7}$$

and

$$k_2 = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]} = 10^{-11}$$

In order to find the proportions of bicarbonate, carbonate and carbonic acid [follows formulae as in *Geobiologie,* 1934]. When we set the total amount of carbonic acid as equal to 100, it can be deduced that:

72 In the 1953 version of *Geobiology* (p. 250-251) Baas Becking gave an historical overview of the development of the osmotic theory, with references to the work of Dutch 19th century scientists as Hugo de Vries, van 't Hoff and van der Waals. He further referred to his work in the Unilever Laboratory in 1943:

The problem of the state of water in colloidal systems was approached from another angle. Gortner approached the problem from a colloid chemical angle, that more advance was made. According to Gortner, water may exist, in a colloid (like protoplasm) in various states: it may exist as free molecules, as molecules bound osmotically or as hydrates and further it may occur as swelling water, tightly bound to hydrophilic, colloidal particles.

Very soon this idea was applied to the problem of hardiness, both against drought and against frost and a number of workers, have attacked the problem from many angles. "Bound" water does not freeze, it remains in the liquid state at low temperatures. The author (1943 unpublished) could demonstrate amylase activity in deep frozen fruit at -25 °C, while fish livers became rancid at this temperature within a few months. There is good evidence to assume that part of the water in a tissue remains unfrozen at low temperatures.

Determinations have been made of the freezing point itself, the expansion at the freezing point and of the latent heat of fusion of ice. The last method seems at least objectionable. It was found that, in general, hardiness increases in plants with an increase of non-freezable water. It should be stated, however, that the road here is beset with pitfalls and that no consensus of opinion exists as to the colloidal "status" of bound water.

Experiments, comparing hardened and unhardened races have to take into account the, often large, differences in water content of these races, the lowering of their freezing point due to osmotically active substances and the water bound as hydrates (*e.g.*, in the carbohydrates).

According to his unpublished bibliography 1948 he wrote the following reports for N.V. Unilever (restricted 1941-1944 and unpublished).

(a) The cytology of the strawberry, with a key to sixty commercial varieties.
(b) The anatomy of the asparagus.
(c) Browning in fruits and the use of dienoles.
(d) Super quick freezing and cell size.
(e) Free and bound water in deep freezing and enzymatic activity.
(f) Methodology of vitamin C determination.
(g) Organoleptic research and the measurement of primary tastes and of odours.

Typescript AAS Basser Library Ms. 043 nr. 161.

73 Reference to Gortner (1930), Gortner (1932). See also Section 5.4.2.

74 Reference to Newton and Martin (1930), Scarth and Levitt (1937).

75 Baas Becking copied the formula, figure and table in this section from *Geobiologie* (1934). See also Section 3.7.2.

$$[H_2CO_3] + [HCO_3^-] + [CO_3^{2-}] = 100$$

$$[H_2CO_3] = \frac{100}{1 + \frac{k_1}{[H^+]} + \frac{k_1 k_2}{[H^+]^2}}$$

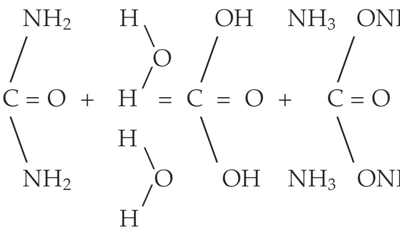
$$[HCO_3^-] = \frac{100}{1 + \frac{[H^+]}{k_1} + \frac{k_2}{[H^+]}}$$

$$[CO_3^{2-}] = \frac{100}{1 + \frac{[H^+]}{k_2} + \frac{[H^+]^2}{k_1 k_2}}$$

Sedimentation, photosynthesis, respiration, changes in pH influence the concentrations remarkably. Changes in the CO_2 and its dissociation are treated in this book in Section 4.6, *Photosynthons*. Of course, CO_2 is, apart from its geochemical importance, the most important nonorganic biological compound.

3.6.3 NH_3 solubility

$[NH_3]$, it forms immediately the highly oxidised base NH_4OH. In nature NH_3 is found in volcanic exhalations and around places where protein or urea is decomposed. Pasteur has discovered the *Urobacilli* and the *Micrococci*,[76] organisms able to decompose urea according to



(ammonium carbonate).

In natural water the content is low, especially when the water is aerated. *Nitrobacter* oxidises NH_4^+ to NO_2^- (see Section 4.7, *Chemosyntonts*).

3.6.4 H_2S

The author [Baas Becking], Van Niel (1932) and Pop (1936) have called attention to the fact that this highly soluble gas shows great similarity to CO_2 as the substances show two dissociation stages k_1 being [9.6] × 10^{-8} and k_2 [1.3] × 10^{-13} [mol.L^{-1}],[77] sulphydryl SH^- (= the univalent radical SH is the sulphur analogue of hydroxyl and constitutes the thiol group) and sulphite S^{2-} on being formed respectively.[78] Van Niel showed that undissociated H_2S is probably toxic to purple sulphur bacteria, while Pop had a similar experience with unicellular green algae. With increasing acidity, the toxic effect mounts rapidly although H_2S is quickly oxidised by oxygen. The lack of an equilibrium condition makes it possible to find oxygen and hydrogen sulphide in same sample. H_2S originates chiefly from sulphate reduction and certainly not from the "pacification of protein", as even various authors (Correns, 1939) claim.[79] See also Section 7.8.8, *Sulphur cycle*.

3.6.5 SO_2

In industrial smoke much SO_2 is usually present, if not removed by Cottrell apparatus or by previous washing. It is quite soluble in water, where it forms sulphurous acid HSO_3.[80] It seems to exert a fatal action on the photosynthetic apparatus of green cells, and forms probably a rather stable compound with chlorophyll, even in low concentrations. In higher concentrations it causes actual burning or bleaching. In the neighbourhood of volcanoes SO_2 is very commonly occurring. On the remarkable occurrence of sulphatic plants (von Faber, 1925).[81] Highly susceptible, at the other hand, are pines and oaks, strawberries and beets. They are veritable test organisms for industrial smelter damage.

3.6.6 Slightly soluble gases: H_2 solubility

Generated by volcanoes. Von Wolzogen Kühr pointed out one interesting way of H_2 generation by metallic iron such as water pipes.[82] This iron would form, with the surrounding soil solution as electric element, where the iron would yield electrons to react with hydrogen ions, forming atomic hydrogen according to:

$Fe + 2\,H^+ = Fe^{2+} + 2\,H$ (see also under sulphate reaction).

Hydrogen is further set free in a great many osmotic bacterial reactions. It easily enters the cycle again, being accepted by a great many organisms, especially the hydrogen organisms, *Hydrogenomonas ruhlandii*:

$$H_2 + \tfrac{1}{2}\,O_2 \rightarrow H_2O + e,$$

e being used to reduce *etc.*[83]

3.6.7 CH_4 and CO, solubility

Methane occurs in volcanic exhalations but its chief source is the anaerobic cellular fermentation, by which enormous amounts of illuminating gas disappear in the atmosphere (consequently the *flatus* of ruminants contains large quantities of methane, methane formed in sheep at 40 litre/day!), "source-gas" = biogas of the farmer in N. Holland. At Groningen city waste is used to make gas. It is probably mostly decarboxylation of fatty acid, however Lieske (1929) showed that CO may be reduced anaerobically to CH_4![84] The CH4 may be oxidised by autotrophs to CO_2, or anaerobically

76 Pasteur described in 1862 an organism consisting of small spherical cells joined together in chains that were capable of decomposing urea, it was named *Torula ureae*. The organism was subsequently named *Micrococcus ureae*. In 1891 Miguel described seven species of *Bacillus*, nine *Micrococci* and one *Sarcina* with the power of decomposing urea.

77 The values of the dissociation constants were taken from the average values in Sun, Nesic and Young (2008).

78 Reference to van Niel (1932) and Pop (1936). In her PhD Thesis Leiden (Baas Becking, supervisor), T. Pop showed that green algae and flagellates are often resistant to H_2S.

79 Baas Becking referred to section *Sulfidische Sedimentäre Lagerstätten* in Correns (1939, p. 209-210).

80 The source to which Baas Becking wished to refer was not identified, however, for a review of the knowledge on solubility of SO_2 at the end 1930s see Beutschlein and Simensson (1940).

81 See also Section 6.4.2.c, *Pollution*.

82 Reference to Carl Adolph Hugo von Wolzogen Kühr, a microbiologist from the Delft school. The classical theory of anaerobic bacterial corrosion, postulated by Von Wolzogen Kühr and van der Vlugt, states that certain organisms, primarily those of the bacterial genus *Desulfovibrio*, remove hydrogen (electrons) that accumulate on the surface of iron (cathodic depolarisation) by means of a hydrogenase, and reduce SO_4^{2-} to S^{2-}. As a result of electron removal, iron dissolves as Fe^{2+} ions at the anode. Baas Becking probably referred to Von Wolzogen Kühr and van der Vlugt (1934).

83 *Hydrogenomonas* species are able to grow autotrophically by means of their ability to oxidise hydrogen gas for energy and to reduce carbon dioxide to cell material. The oxidation of hydrogen is accomplished by the hydrogenase system which catalyses the reaction $H_2 \rightarrow 2H^+ + 2e$. Providing that electron transport occurs *via* the cytochrome system with the reduction to water, 3 moles of ATP would be expected *per* mole hydrogen oxidised. See Sokatch (2014, p. 194).

84 Reference to the work of Lieske (1929) in German coal mines. See Fischer, Lieske and Winzer (1932, p. 2).

transfer H (Gailey). CO originates probably from HCOH and occurs in the bladders of the giant brown seaweed *Nereocystis lütkeana* (5 %) (Hoagland, 1915).[85]

3.6.8 O_2 solubility

It is misleading to express O_2 as cc/L or mg/L, as this is a function of temperature. Much better is % saturation! Probably originated by photosynthesis action from *water.* With H_2 and CO_2, the most important biological gas. Accepted by specific enzymes (yellow enzyme of Warburg, red haemo and Ca oxide),[86] it reacts with the hydrogen as the substrate. Water may become easily saturated in mg/L up to 300 % (the same is true of $CaCO_3$, also 300 %, see Wattenberg, 1938, *Meteor*).[87]

3.6.9 N_2 solubility

79 % of atmosphere. Enters into the cycle only through 3 bacteria and bluegreens, (molybdenum catalyst) to form NH_3. Equilibrium with water slowly obtained. It may be used to determine origin of natural water, using solubility as a function of temperature. Nitrogen is also formed by nitrate reduction, which is active even in highly saturated brines. In seawater it shows less activity, especially in the aerated surface water.

3.6.10 $CH_2 = CH_2$ ethylene

Biogene of biological origin. Ripening of fruits (Molisch, F. Denny). Technically prepared from alcohol by means of phosphine acid, PH_3. Molisch discovered (1937) the effect of the emanation of ripe apples upon the growth of tomatoes.[88] Denny (1924) recognised acetylene as active (6 parts *per* 10^6) in bleaching celery, ripening of bananas (citrus fruit).[89] Nicolai and Baas Becking (1935) found that it could ferment tobacco.[90] Gouwentak (1941) proved that it could break dormancy in buds.[91]

See further Section 7.2, *Ergones* on enzymes. In Plate 3.3 on graphical chemistry, the position of the gas is shown to be unique. [Ethylene is represented as “i”.]

[Baas Becking (1959) described the equilateral triangular plot on Plate 3.3 with compounds C – 4H - 2O in more detail:]

In order to represent changes in composition of organic matter (simplifying the processes to changes in C, H, and O) we may represent the relations in a triangular diagram (Baas Becking, 1947b) if the corners represent C, 4H, and 2O respectively. The point representing CO_2 will be halfway on the C–2O line, while CH4 and H_2O occupy analogous positions on the other sides. It is easy to show that all substances with a reduction level of O will be situated on the line H_2O - CO_2, all substances with a reduction level 8 on the line H_2O - CH, while the line C - H_2O (“carbo – hydrate”) shows the reduction level 4.

A bundle of lines passing through H_2O represent (de) hydrations, a bundle through 4H represent (de)hydrogenations, while the bundle through CO_2 represent (de)carboxylations and that through 2O (de)oxygenations.

3.6.11 Water vapour

In the atmosphere up to 17.28 g/litre, has great effect upon thermal properties of atmosphere, upon wind formation and radiation, blanketing. [Baas Becking referred to table ‘Composition of Atmosphere at various levels’ according to Humphreys (1926) in *Critical Tables I* (p. 393).][92]

Water vapour may be absorbed by various organisms. Enters and leaves every leaf. See further Section 5.10.4.

3.6.12 Other gases and summary

It is a remarkable fact that the organisms occurring in the black mud, in hot springs and those in strong brines should show many points in common. It may be that the dictating factor here is the oxygen, or rather the absence of oxygen. The solubility of the gas in weak brines (saturated NaCl) is only 1/9 of that in freshwater while at high temperatures the solubility is also reduced materially. On the black mud the oxygen tension is practically zero. (For functions of oxygen see Section 5.10.12). The work of E. Reuter however tends to show that at least for higher plants, a diminution of the oxygen

85 Baas Becking probably referred to papers of Langdon and Gailey, who showed that there was present an average of 4 percent (by volume) of carbon monoxide in the pneumatocyst of the giant Pacific Coast kelp, *Nereocystis Luetkeana.* See Langdon (1917), Langdon and Gailey (1920).
“Hoagland” refers to Dennis Robert Hoagland (1884-1945) Professor of Plant Nutrition at University of California at Berkeley (1927-1949).

86 Otto Heinrich Warburg (1883-1970), German biochemist, awarded Nobel Prize for Physiology and Medicine in 1931 for his research on respiration. By 1932 Warburg had isolated the first of the so called yellow enzymes, or flavoproteins, which participate in dehydrogenation reactions in cells, and he discovered that these enzymes act in conjunction with a non-protein component (now called a coenzyme), flavin adenine dinucleotide. In 1935 he discovered that nicotinamide forms part of another coenzyme, now called nicotinamide adenine dinucleotide, which is also involved in biological dehydrogenations.

87 Baas Becking referred to the work of Wattenberg (1938) on the $CaCO_3$ saturation of seawater in the Atlantic Ocean, referred to in Table 40 (p. 192) in Correns (1939). See also Section 3.6.8.

88 Reference to Molisch (1911) and Molisch (1937). Hans Molisch published already in 1884 about the effect of gases on plants: Molisch (1884). In 1937 Molisch published, *Der Einfluss einer Pflanze auf die andere Allelopathie.*
It is remarkable that Baas Becking did not refer to the Utrecht PhD Thesis of Pieter Adriaan van der Laan (1934*), Der Einfluss von Aethylen auf die Wuchsstoffbildung bei Avena und Vicia.*
See for review Michael Evenari (1961) Chemical influences of other plants (allelopathy).

89 Reference to Denny (1924, 1927). In 1923, Denny secured a patent covering the use of ethylene for the forced colouration of fruit. (U.S. Patent No. 1,475,938). See also Wray-French (2013).

90 Nicolai and Baas Becking (1935). Marie Françoise Emilie Nicolai (1900-1961) was assistant of Baas Becking in the Leyden Botanical Laboratory.

91 Reference to Gouwentak (1941). Cornelia Adriana Gouwentak (1902-1977), plant physiologist in Wageningen, married her teacher professor Dr. E. Reinders. January 2, 1960, a Bulgarian student Josif Lulev fired three shots with a pistol on her because she refused to let him pass his examination. She survived the assault with a bullet in her shoulder. Lulev was sentenced to 11 months in prison. When he was released, he left for Freiburg, Germany, where in 1964 he does what Cornelia Reinders-Gouwentak considers impossible. He graduates in forestry and gets his PhD there five years later.

92 Baas Becking probably intended to include the table, from the *Critical Tables* I of Humphreys (1926, p. 393). In the 1953 version of *Geobiology* (p. 88) he included the table. Baas Becking wrote in *Geobiology* (1953, p. 85-86):

> *Water vapour* forms another very important part of the lower atmosphere. The atmosphere’s water vapour content decreases at first with increasing altitude; but at very great heights it increases again. That water vapour does not follow gravity laws as the other gases is due to its high boiling and melting points. At the low temperatures at higher altitudes water condenses (on dust particles as nuclei) and forms liquid water drops and even ice crystals, forming clouds which though heavier than air are born by air currents.

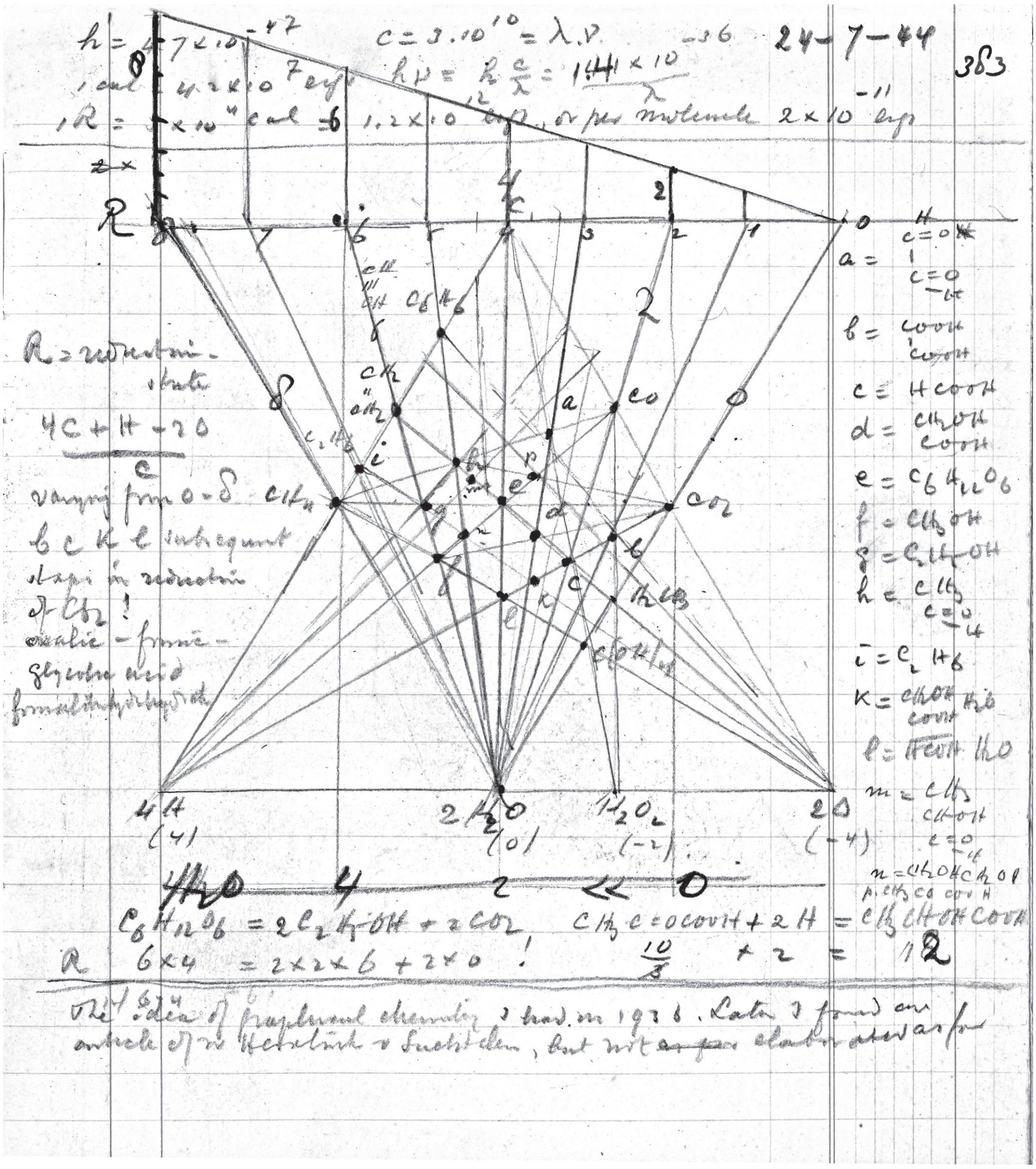


Plate 3.3 Equilateral triangular plot with compounds of C – 4 H – 2O, relating changes in the composition of organic matter to the reduction state of the organic matter. [Baas Becking added:] The idea of graphical chemistry I had in 1936. Later I found an article of Hesselink van Suchtelen,[93] but not elaborated as far.[94]

pressure to 1/9 does not materially return the vital functions.[95] This finding is corroborated by the data obtained with lower forms, when the oxygen starts to be limiting factor at very low pressures. Phylogenetically we need not wonder at this, if we adhere to the theory of V.M. Goldschmidt concerning the photosynthetic origin of the atmosphere oxygen. Extreme anaerobic we might only expect in the most recent forms, the so called "higher" plants and animals.

3.7 Acids and Bases

3.7.1 Introduction

The chief causes of acidity and alkalinity in the natural milieu are the *carbonic acid, the sulphuric and hydrochloric acids,* and their dissociation and reduction products, organic acids play a subordinate role.

93 Frans Herman Hesselink van Suchtelen (1884-1937), published research in soil chemistry. He died as a result of an accident at Apeldoorn on June 23, 1937, at the age of fifty three years. Van Suchtelen was for some years connected with the New Jersey Agricultural Experiment Station, the Michigan State College and the Massachusetts Agricultural College. See *Science* 23, 86, 2221, p. 73, July 1937. Baas Becking probably referred to Hesselink van Suchtelen (1931).

94 Baas Becking (1947b) published his method for graphical representation of the properties of three chemical components by means of an equilateral triangle in 1947 in an article signed 'Leiden Buitenzorg 1945-1946'. The figure in the manuscript is Figure 1 in the 1947 publication. In 1947 Baas Becking did not refer to Hesselink van Suchtelen. The presentation of results by means of an equilateral triangle was described in *Geobiologie* (1934), with reference of unpublished results by himself and Dr. A. Massink. In 1934 Baas Becking and Massink published their recently developed method of description of natural waters in *On the Changes in the Composition of Natural Waters* (Baas Becking and Massink, 1934).
In the introduction of the manuscript of *Geobiology* (1953) Baas Becking described the triangular representation of data again (p. 9-10):

> G.G. Stokes, in 1891, proposed a graphical representation of the properties of three components by means of an equilateral triangle, and this method has been used ever since, chiefly in phase rule work and in soil science. The representation is based upon the well known property of an equilateral triangle; the sum of the distances of any point within this triangle to the sides is constant. A complex of three variables may be represented by this method showing a considerable advantage of the, more usual, plane representation of a space model. It widens our scope in many respects and allows of a welcome extension of the visual methods, so dear to the biologist (Baas Becking, 1947b).

95 Possibly reference to the Finnish entomologist, Professor Enzio Reuter (1867-1951), Helsingfors.

3.7.2 CO_2 equilibrium

The equation developed in Section 3.6.2 may be extended by the concept of excess base.[96] If we write:

$$[HCO_3^-] + 2\,[CO_3^{2-}] + [OH]- = [H^+] + [B]$$

[B] represents the excess base as its order of magnitude is usually much higher than $[H^+]$ we may write the equation (Johnston):[97]

$$[HCO_3\text{-}] + 2\,[CO_3^{2-}] = A \text{ (Wattenberg).}$$

Continuing Johnston's equation with those derived in Section 3.6.2 (Michaelis),[98] we get:

in which kw = dissociation [constant] of water [= 1.0×10^{-14}], or as $1/2k_1k_2$ is very small

$$k_1[H_2CO_3] = [B][H^+] + [H^+] - k_w$$

For B = 0 and for $CO_2 = 10^{-4}$, pH = 5.8. Titrating the water with 0.01 HCl with methyl orange or methyl acid to endpoint ± pH 5 gives B. For seawater this is 25×10^{-3}. Borates may influence the result slightly.

3.7.3 Sulphate and sulphides

Wattenberg and Timmerman (1936) have investigated the condition of CO_2 in seawater, especially in relation to lime deposition. Increase in $[H^+]$ will cause $CaCO_3$ (K_{CaCO_3} ~10^{-8}) to dissolve and inversely.

Increase of temperature changes K_2 more than K_1, hence an increase in CO_3^{2-} pressure causes an increase in solubility, and increase in $[H^+]$. Pure NaCl increased the solubility of $CaCO_3$, which is counteracted in seawater by other ions. Taken all in all the influences tend to counteract one another, so that the solubility of $CaCO_3$ in seawater is the same as that in freshwater (± 30 × concentration of CO_3 in air).

See further Section 3.5.2, *Swelling pressure*, Section 6.6.5, *Lime deposition* and Section 7.8.8, *Sulphur cycle*. The original paper by Wattenberg and Timmerman, *Ann. Hydrog. Berlin* 64 (1936), p. 23, should be consulted.[99]

3.7.4 Ammonia and nitrates

[Baas Becking left this section blank.]

3.7.5 Borates and phosphate

[Baas Becking left this section blank.]

3.7.6 Hydroxides

[Baas Becking left this section blank.]

3.7.7 Solubility of cations and anions

[Baas Becking inserted Fig. 3.11.]

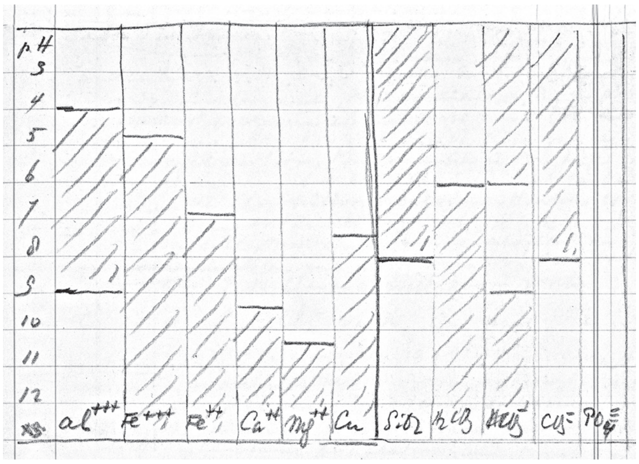


Figure 3.11 Solubility range of cations and anions related to pH (shaded areas).

3.7.8 Origin of acid in bog water

[Baas Becking left this section blank.]

3.7.9 Summary and conclusions

[Baas Becking left this section blank.]

3.8 Inorganic Substances

3.8.1 Introduction

We shall only give a brief summary of those elements that directly concern living matter and enter into dealings with living matter. We shall conclude the so called minimum elements; they are dealt with in Section 5.8, *Minimum Elements*. Of these "primary" biogenic elements we name fourteen, all of low atomic number (1-28), six of them metals. According to several authors, this number is too high, we should exclude Na, Al and Si, it is even claimed that certain organisms may develop without calcium, however, experiments in this direction being extremely difficult, it is better to reserve judgment in this case. Most of the mineralogical and geochemical information has been taken from Clarke's (1916) well known work.

Bioelements: H, C, N, O, S, P, Cl, Na, K, Cu, Mg, Fe, Al, Si.

3.8.2 Hydrogen

22 % of the lithosphere, 10.67 % of hydrosphere, overige [Dutch word for 'other'] 0.95 %. In all rocks, either as included moisture, or as hydroxyl. With carbon the most important element in organic substances, where it functions as the universal fuel substance. Frequent in a native state in rocks, in volcanic exhalations, and formed by the reduction of organic matter or the ionisation of metallic iron.

96 Baas Becking copied the formulas of Michaelis from Chapter V of Geobiologie (1934) on one of the first pages of the manuscript of Geobiology (1944), left of the first page of the table of contents.

97 Reference to 'Johnston' unknown. Possibly James Johnstone (1870-1932), Scottish biologist and oceanographer.

98 Reference to Leonor Michaelis (1875-1949), German biochemist, known for his work on enzyme inhibition, pH and quinonens as well as for his work with Maud Leonora Menten (1879-1960) on enzyme kinetics published in 1913. Baas Becking referred to Michaelis (1914). The calculation was taken from *Geobiologie* (1934, p. 40-43 English edition, 2016).

99 Baas Becking referred to Wattenberg and Timmerman (1936).

3.8.3 Carbon

19 % of the lithosphere, 0.002 % of the hydrosphere, average 0.18 %. Characteristic of all organic compounds, native as graphite (laminar lattice) and diamond (tetragonal lattice) or as coal (amorphous). Carbon dioxide 0.03 % of atmosphere air. Natural gas, petroleum and paraffin are essentially hydrocarbons. Carbonic acid is in natural waters, enormous sedimentary rock masses of calx [= lime] to aragonite $CaCO_3$ or dolomite to $CaMg(CO_3)_2$, siderite $FeCO_3$. In magmatic silicates only as cancrinite $Al_3Na_4HCSi_3O_{15}$. Methane CH_4 in volcanic exhalations is found by cellulose fermentation. See further Section 7.8.6, *Carbon cycle*.

3.8.4 Nitrogen

Nitrogen is practically confined to the atmosphere (79 %), only 0.03 % of the known terrestrial matter. Of primary importance in organic matter, especially in proteins. Nitrogen is also a constituent of the important class of compounds known as porphins (chlorophyll, haemoglobin, enzymes). Volcanic water contains ammoniac compounds, electric storms may form some nitric acid, but all the rest is biogenic including the nitrate beds, as in Chile. Several microbes are able to reduce atmospheric nitrogen. Microbes and green plants are able to reduce nitrate to ammonia. See further Section 7.8.7, *Nitrogen cycle*.

3.8.5 Oxygen

47.33 % lithosphere, 85.79 % hydrosphere, average 50.02 %. According to Goldschmidt the earth crust is a "crystalline oxygen lattice with other elements interspersed"; oxysphere (Goldschmidt, see p. 36). The most abundant of elements, forming more than one half of the terrestrial elements. In the free state it constitutes about one fifth of the atmosphere, and in water it is "the chief element of the ocean" (Clarke, 1916, p. 18). All the important rocks contain ±50 % oxygen. The atmospheric oxygen probably is derived from the photosynthetic activity of green plants (Kelvin, Goldschmidt), which is the analysis of water into its elements. Rocks do not contain oxygen carriers such as haemoglobin and haemocyanin. See further Section 5.10.11, *Oxido-reductions, oxygen*.

3.8.6 Sulphur

0.12 % of lithosphere, 0.09 % of hydrosphere, average 0.11 %. Native (*e.g.*, Girgenti, Sicily, W. Texas, Java), as sulphides, especially those of iron FeS (hydrotroilite), and FeS_2 (pyrite, marcasite and meinicovite). In the ocean as sulphate mainly, further gypsum $CaSO_4$.2aq and anhydrite $CaSO_4$. Sulphides and sulphate in volcanic deposits, and further formed by microbial reduction of sulphates. In igneous rocks as hauynite $Al_3Na_3SSi_3O_{16}$ [= $Na_3Ca(Si_3Al_3)O_{12}(SO_4)$] and nosean $Al_3Na_5SS_{13}O_{16}$ [= $Na_8Al_6Si_6O_{24}(SO_4)\cdot(H_2O)$]. Abundant in olia, petroleum, alky sulphides, also in coal. A primary biological element, particularly important in the amino acids cysteine, cystine and methionin, and as such an integral element in hair and horn. This reduced form of sulphur is made by green plants from sulphates, which are the only form of sulphur that the plant can use. Further in the plant as thiocyanate (mustard oil C_3H_3-CNS) as sulphide (mercaptane *e.g.*, C_4H_9SH in *Lysichiton*). In the animal body in chondria paired sulphates. See further Section 7.8.8, *Sulphur cycle*. In sulphur bacteria rhombic sulphur and formation of sulphuric acid.

3.8.7 Phosphorus

0.0011 % of known terrestrial matter. In meteoric rock as phosphine PH3, otherwise always as phosphate. Chief minerals are the apatites $Ca_5(PO_4)$ F and $Ca_5(PO_4)Cl$ (magmatic) other minerals all of biological origin as P is important part of many crustacean shells (*Lingula*, 91 %) and of bone. From such phosphates are derived phosphoric increments of a deep sea, containing up to 24 % P_2O_5, the blue vivianite from our marshes $Fe_3P_2O_8.8H_2O$, the several species of guano phosphate *etc*. Living matter is probably unable to reduce the phosphate to phosphine. Phosphate occurs in living matter chiefly in the lecitinoids and in the nucleic acids. Absorption by green plants as H_2PO_4- ion.

3.8.8 Sodium

2.46 % of the lithosphere, 1.14 % hydrogen, average 2.36 %. In magmatic rock in many feldspar such as albite $NaAlSi_3O_8$, nephelines such as aplite $NaAlSiO_4$, pyroxenes such as aegirine NaFeSi2O6. Abundant in rock salt, halite NaCl, further as a playa deposit trona $Na_2CO_3.NaHCO_3.2H_2O$, soda nitre in Chilian caliche. In nearly all natural waters, accumulated in the ocean as chloride dispersed in the atmosphere (cyclic salt). Probably necessary for animals and certain plants, Antagonist calcium.

3.8.9 Potassium

2.46 % of the lithosphere, 0.04 % of hydrosphere, average 2.28 %. In magmatic rock chiefly in feldspar such as orthoclase $KAlSi_3O_8$, mica's such as muscovite $Al_3KH_2Si_3O_{12}$ and leucite $KAlSi_2O_4$. Nearly all terrestrial water contains it, which is early exchanged by zeolite action. Saline beds near Stanford, Mülhausen and from Searles Lake, California. Kelp is an abandoned source. Accumulated also by higher plants. The most important vital metal, exchanged activity by cell and environment, chiefly as K_2HPO_4.

3.8.10 Calcium

3.47 % of the lithosphere, 0.05 % hydrosphere, average 3.22 %. As sulphide in meteorites, in magmatic rock anorthite $CaAl_2Si_2O_8$, garnet $Ca_3Al_2Si_3O_{12}$, further epidote, amphibole pyroxenes and scapolite. Fluorspar CaF_2 and apatite $Ca(PO_4)_3$. As carbonate *e.g.*, in calcite, aragonite and dolomite. As sulphate in gypsum and anhydrite. A very important biogenic metal and closely connected with cyclic biological phenomena. In bones, teeth and carapaces, in a great many plants preponderantly as lime.

3.8.11 Chlorine

0.06 % of lithosphere, 2.07 % of hydrosphere, average 0.20 %. In magmatic minerals such as sodalite $Al_3Na_4Si_3O_{12}Cl$ and the scapolites. Further in halite, from oceanic deposits and the K salt carnallite $KClMgCl_2.6H_2O$. Free Cl_2 and hydrochloric acid in volcanic emanations. In the atmosphere oceanic NaCl. $FeCl_3$ in meteorites. The chief cause of the acidity of sphagnum bogs (Baas Becking and Nicolai, 1934; Thompson *et al.*, 1927).[100] Necessary for animals, in known 0.6-0.9 % NaCl. Free chlorine (?) in the stomach of mammals. Cl- ion is physiologically rather inert. See sodium.

100 Baas Becking and Nicolai (1934); Thompson *et al.* (1927).

3.8.12 Iron

4.5 % of the lithosphere, average 4.18 %. Next to aluminium the most abundant metal; native iron, however, is rare. In practically all rocks, particularly in amphiboles, pyroxenes, olivines and micas. In seawater as FeF_3, oxide magnetite Fe_3O_4 and haematite Fe_2O_3 and FeO. As hydroxides (partly bacterial in formation) limonite $2Fe_2O_3.3H_2O$, further tungite, goethite, xanthosidentite and chimentite. Glauconite, possibly coprolite of echinoderms, $FeKSi_2O_3$.aq., as sulphides FeS hydrotroilite, FeS_2 pyrite and marcasite, $FeCO_3$ siderite besides a great many silicates, phosphates *etc*.

Functions as very important biological metal is coupled to its variable valency. Integral part of many enzymes and red blood pigment, in porphines. At high pH is soluble enough to cause agricultural troubles (citrus, peas, chloriosis). At low pH so soluble that soils may become depleted (podsol). Tropical weathering of soil causes red earth later to be found.[101]

In geosphere [?] 7.3 % Fe_2O_3 (Clarke, 1916), oceanic seawater 1.9-9.6 %, rivers <1 mg/L, ocean 1-10 γ/L [10-6 g/L].

$[Fe^{3+}][OH]^{3-} = 10^{-38.6}$ or Log $[Fe^{3+}]$ = 4.1–3 pH. [= 3.4 - 3 pH]

$$FeOH^{2+} + H^+ \leftrightarrows Fe^{3+} + H_2O$$

$$K = [FeOH^{2+}][H^+]/[Fe^{3+}] = 3.7 \times 10^{-3} \text{ or log } [FeOH^{2+}]\ 1.7 - 2\ pH$$

$$4\ Fe^{2+} + O_2 + 2\ H_2O \leftrightarrows 4\ Fe^{3+} + 4OH^-$$

$$\left.\begin{aligned} E_{Fe} &= 1.983 \times 10^{-4}\ T\ (\log [Fe^{3+}] - \log [Fe^{2+}]) + 0.77\ (T = 291) \\ E_{O2} &= 1.983 \times 10^{-4}\ T(1/4 \log P_{O2} - \log [OH^-] + 0.41 \end{aligned}\right\} \text{equal}$$

$$\text{Log } [Fe^{2+}] = -2\ pH - \tfrac{1}{4} \log P_{O2} - 4.00.$$

Water in equation $P_{O2} = 0.206$. For $P_{O2} = 1.7 \times 10^{-29}$ (dissociation water vapour at 17 °C) we get more iron in solution.

[Baas Becking inserted Figs 3.12 and 3.13.]

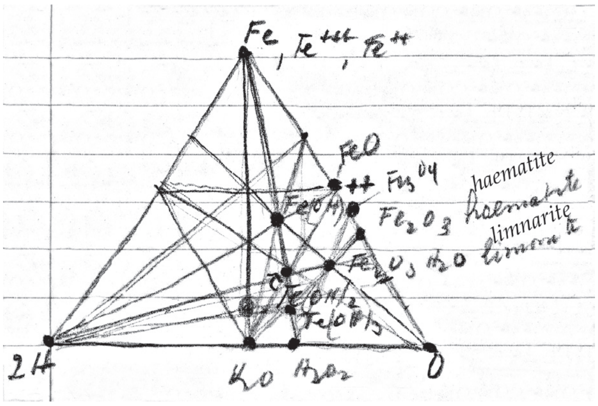


Figure 3.12 Equilateral triangular plot with compounds of Fe – 2H - O. Showing Fe^{3+}, Fe^{2+}, FeO, Fe_3O_4, Fe_2O_3 haematite, Fe_2O_3 limonite.

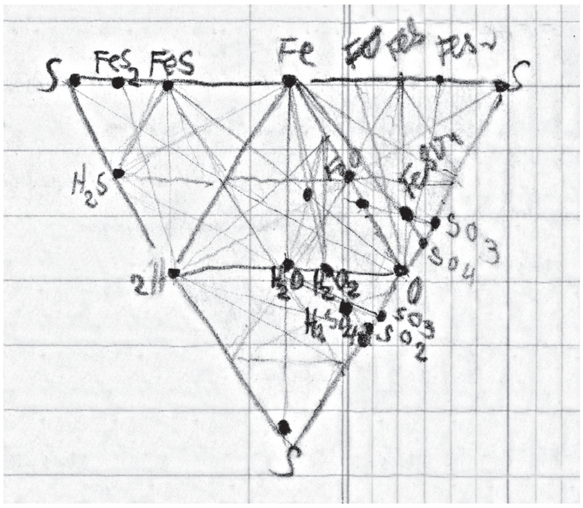


Figure 3.13 Equilateral triangular plot of Figure 3.12 extended with compounds of S. [Baas Becking wrote on top of the figure:] V[on] Wolzogen Kühr.

See also Cooper (1935, 1937): Some conditions governing the solubility of iron, *Proc Roy Soc London* B, 124, p. 299 (1937); Iron in the sea and in marine plankton. *Proc Roy Soc London* 118, p. 419 (1935).[102] [See Fig. 3.14.]

High acidity and low pO_2 make iron more soluble. The articles of Cooper should be consulted in the original. In seawater the iron is present as practically undissociated FeF_3. The older literature mentions ferrates, most probably these compounds do not exist. In the considerations of Cooper, no mention is made of *ferrites* and *ferrates*, compounds in which iron is present in anionic form, such as in the above example, Al is soluble at higher alkalinities as aluminate. Cations may be taken in by exchange while anions require much respiration energy. Still, if the anion is mobile, not only plasmatical, out of the acid vacuole, the ferrite would automatically give off natrium of iron. It seems that no consideration of an element is complete without taking into account all of its possible modes of occurrence. The question requires further investigation.

[Baas Becking inserted Fig. 3.14, drawn after Correns (1939, Abbildung 45, p. 202).]

101 Reference not identified.

102 Reference to Cooper (1935), Cooper (1937). For L.H.N. Cooper see also Section 6.1.2 under *Iron*. According to Cooper (1935) it seemed possible that in seawater with solutions containing more than 100 mg fluoride ion *per* litre, ferrifluoride might prove more difficult to reduce than ferric iron.

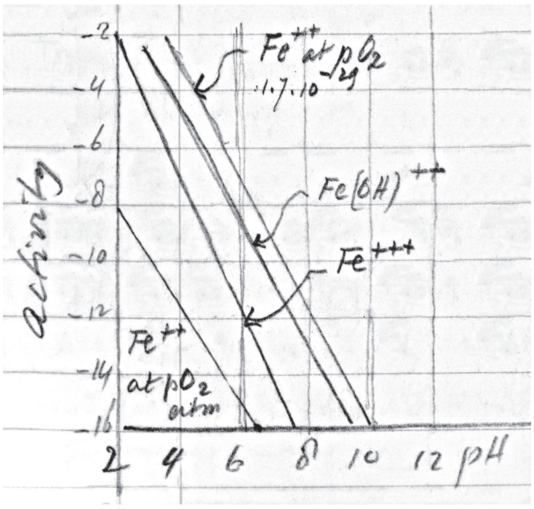


Figure 3.14 Solubility of iron (log of activities), which approximately corresponds to the concentrations depending on pH: a. solubility of Fe^{3+}; b. solubility of $FeOH^{2+}$; c. Solubility of Fe^{2+} in water that is in equilibrium with the oxygen in the atmosphere (pO_2 = 0.206); d. Solubility of Fe^{2+} at pO_2 = $1.7.10^{-29}$. After Correns (1939, Abbildung 45).

3.8.13 Silicon

27.74 % of the lithosphere, average 25.80 %. Oceans, in all rocks, except coastal water. Varieties of quartz, very common. In all natural waters, deposited as sinter from volcanic water. Solubility as given in Correns (1939, p. 129).[103] See Figure 3.15. Al silicates found between pH 4-5 and >pH 11. Necessary for many organisms as functional element. "Carrier" element of soil.

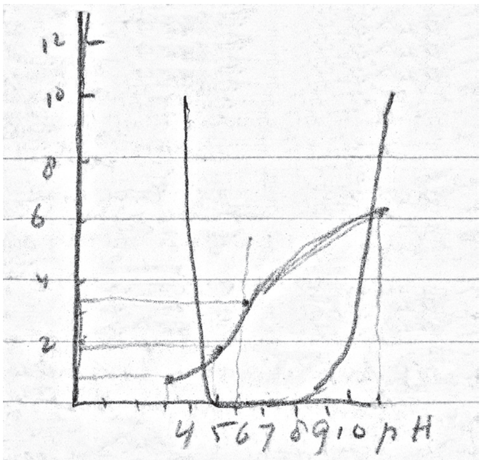


Figure 3.15 Solubility of SiO_2 (a) and Al $(OH)_3$ (b) depending on the pH. After Correns (1939, p. 129).

3.8.14 Aluminium

7.85 % of the lithosphere, average 7.30 %, the most abundant of metals. With the exception of the fluoride, it always occurs in the oxidised state. In all rock, except sandstones, silicates, but also as Al_2O_3 corundum, as $Al(OH)_3$ bauxite (tropical weathering of silicate rock) and AlF_3 cryolite. Although not primarily necessary, it is present in the ash of most organisms, notably in higher plants (*Lycopodiacea*, *Symplicos*). Its solubility is very low at pH 5-9, after a fashion, this solubility is antagonistic to that of SiO_2.[104] At very low pH aluminium dissolves and yields very acid solutions (alum lakes).[105]

3.8.15 Magnesium

2.24 % of lithosphere 0.14 % hydrosphere, average 2.28 %. In pyroxenes, amphiboles and olivine, serpentinite $H_4Mg_3Si_2O_9$. From enstatite $CaMg_3Si_4O_{12}$, talc is derived; $H_2Mg_3Si_4O_{12}$. Further, in sedimentary rock as dolomite $CaMg(CO_3)_2$ and magnesite $MgCO_3$. Brucite is derived from talc and serpentinite, $Mg(OH)_2$. The abundant metal is never found native. Very important in seawater, dolomitisation of organisms is secondary to lime formation. In green plants an integral part of the chlorophyll, also present in certain enzymes, as an ion it shows affinity to alkali metal ions.

3.8.16 Summary

[Baas Becking inserted Fig. 3.16 and Table 3.4.]

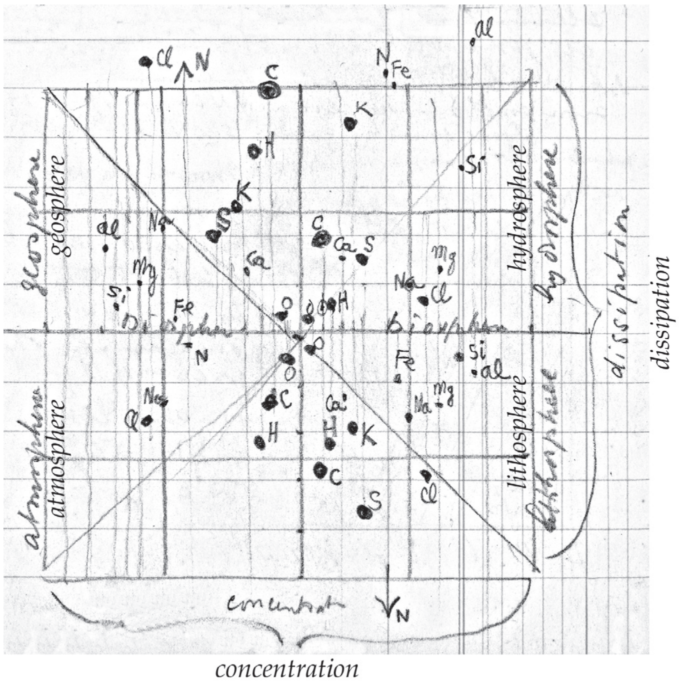


Figure 3.16 Relative frequency of elements in the Geosphere, Lithosphere, Hydrosphere, Biosphere and Atmosphere (see Table 3.4), and indications of trends to concentration and to dissipation.

103 The reference is to Correns (1939, Abb. 3 p. 129).

104 According to Britez *et al.* (2002):
the formation of an Al-Si complex in the shoot tissues of *F. marginata*, may substantially contribute to the internal detoxification of Al.
See also Taylor, Jugdaohsingh and Powell (1997).

105 According to Baas Becking the acidity in Alum lakes in Western Australia is due to hydrolysis of salts of heavy metal. See Baas Becking (1938a), *On the Cause of the High Acidity in Natural Waters, Especially in Brines.*

Table 3.4 Relative frequency of elements in the geosphere, lithosphere, hydrosphere, biosphere and atmosphere.

	Relative Frequency				
	Geosphere	Lithosphere	Hydrosphere	Biosphere	Atmosphere
Fe	1	4	20	9	
O	2	1	1	1	2
Si	3	2	13	14	
Mg	4	6	5	12	
Ca	5	5	6	4	
Ni	6	–	–	–	
Al	7	9	25	15	
S	8	15	6	6	
Na	9	7	4	10	6
K	10	8	17	5	
H	11	9	2	3	3
C	12	10	6	2	5
Cl	22	12	3	11	7
N	50	50	21	8	1

3.9 Organic Substances

G. Harmsen (diss.), *Aerobe cellulose aantasting* [Aerobic cellulose affects] (in press).[106]

3.9.1 Introduction

[Baas Becking inserted Fig. 3.17.]

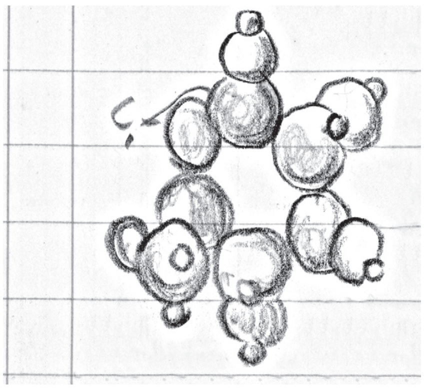


Figure 3.17 Glucose ring formed by five carbon and one oxygen atom.

We shall start with the primary anabolite, glucose. This is, as a solid, at least a heterocyclic compound, the ring formed from 5 C atoms and one oxygen. The compound originates from perhaps six superimposed chlorophyll matrices, by transference of hydrogen from water to carbon dioxide. It may be that ascorbic acid is either an intermediary or that it plays a role as catalyser. β Glucose is the central substance of biochemistry after J. Mark.[107] It is the starting point for the formation of organic acids (Kluyver), of fats (Haehn and Kintoff, 1923 and 1924), of protein (Knoop, Oesterlin, Chibnall),[108] and of the great number of other classes of substances. β Glucose may be broken down by all, or nearly all organisms (see Section 7.1, *The Concept of Symbiosis and Antagonism*). It is rarely present in the outer milieu, as it is such a universal food.

3.9.2 Pectine substances, cellulose

Cellulose, pectine, chitine, lignine are present in the outer milieu. Cellulose is found from β glucose by dehydration, one water molecule disappearing between two sugar molecules. It forms long chains. Pectine is the methylester of pectic acid, chiefly galacturonic acid, together with cellulose and hemicellulose. Chitine is a chain glucose where, in every glucose molecule, one amino group is present instead of an OH. The molecule is moreover acetylated. Lignine is already aromatic shows the graphite lattice. It contains aldehydes and methoxy groups. All these polymeric substances have to be hydrolysed by means of enzymes before they may enter into metabolism. This seems to be particularly hard in the case of chitin, which is found, as such, even in certain *Trilobites*. Benecke (1905) described a *Bacillus chitinovorus* which is, however, only able to attack chitin if other organic food is offered as well.[109] Other polymers may be named, sufficient to state that in the majority of cases they represent in the milieu. In summary: energy yielding food.

3.9.3 Formation of organic acids

[Baas Becking left this section blank.]

3.9.4 Summary and conclusions

In the section on metabiosis or succedaneous symbiosis (see Section 7.6, *Heterosymbiosis, succedaneous (Metabiosis)*).

3.10 Other Organisms

3.10.1 Introduction

[Baas Becking left this section blank.]

3.10.2 Influence: physical milieu

[Baas Becking left this section blank.]

3.10.3 Influence: chemical milieu

[Baas Becking left this section blank.]

3.10.4 Summary and conclusions

[Baas Becking left this section blank.]

106 Reference to *Onderzoekingen over de Aerobe Celluloseontleding in den Grond* (1946, Groningen PhD thesis of Georg Wilhelm Harmsen (1903-1981), soil microbiologist who worked in the 1930s in the reclaimed polder Wieringermeer on pyrite oxidation and decomposition of cellulose in soil. Although he completed his thesis in 1939, the public defence had to be postponed until 1946. See Mulder (1982).

107 Baas Becking referred to Herman Franz Mark (1895-1992), Austrian-American chemist. He received on July 5, 1944 in the Utrecht prison from C.J. Niekerk-Blom a copy of Mark's *The General Chemistry of High Polymeric Substances* (Mark, 1940). See also Section 5.1.3.

108 Reference to Knoop and Oesterlin (1925). Also reference to Chibnall (1939).

109 For Benecke (1905) see also Section 6.4.4.e.

3.11 Law of Limiting Factors

3.11.1 Introduction

[Baas Becking left this section blank.]

3.11.2 Minimum Law of Liebig

[Baas Becking inserted Fig. 3.18.]

Mitscherlich.[110]

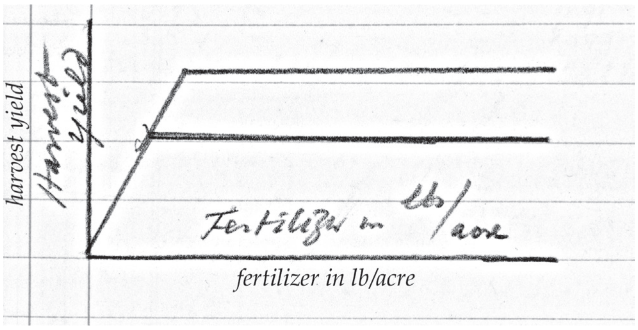


Figure 3.18 Relation between harvest yield and fertiliser in lb/acre for two growth factors.

3.11.3 Blackman's optimal and limiting factors[111]

[Baas Becking left this section blank.]

3.11.4 Milieu factor (optima)

[Baas Becking left this section blank.]

3.11.5 Summary and conclusions

[Baas Becking left this section blank.]

3.12 Soil, Lithosphere

3.12.1 Introduction

Rock decomposition is partly mechanical, partly chemical. Chemical decomposition is by water and carbon dioxide, yielding a solution of SiO_2, alkali carbonates, alkali phosphates, lime, and siderite of which some oxidises to magnetite or haematite, pyroxenes and amphiboles go into solution most readily, then follow the plagioclase, feldspars, then orthoclase and mica, while muscovite is the most resistant of all (Clarke, 1916). The matrices may crumble and a "sieving" action of wind and water may set in, sorting the material as to size. As end products of the decomposition we get *soils*, with, as extremes, sand, laterite, kaolinite, bauxite. Table 3.5 taken from the classical work of Müller (1877), showing % of rock dissolved and % of undissolved mineral (seven weeks digestion in carbonated water).[112]

3.12.2 Origin of soils

[Baas Becking inserted Fig. 3.19, recalculated from Clarke (1916, p. 490).]

Table 3.5 Percentage of rock extracted from minerals by carbonated water. From Clarke (1916), after Müller (1877).

	SiO_2	Al_2O_3	K_2O	Na_2O	MgO	CaO	P_2O_5	FeO	Total %
Adularia	0.1552	0.1368	1.3527	–	–	–	–	tr	0.328
Oligoclase	0.237	9.1713	–	2.367	–	3.213	–	tr	0.533
Hornblende	0.419	tr	Tr	–	–	8.528	–	4.829	1.536
Magnetite	tr	–	–	–	–	–	–	2.428	1.821
Apatite	–	–	–	–	–	2.168	1.822	–	2.088
Olivine	0.873	tr	–	–	1.291	–	–	8.733	2.111
Serpentine	0.354	–	–	–	2.649	–	–	1.527	1.211

110 In the 1953 version of *Geobiology* Baas Becking gave a detailed section on *The Influence of the Environment on Vital Processes* (p. 410-428). He summarised the work of Liebig, Blackman en Mitscherlich as follows:

> The organism is subject to a multiplicity of external factors and the integration of these factors, at a given moment determines, in many cases, the intensity of a vital function, such as growth, photosynthesis or respiration. At first sight it would seem a hopeless task to analyse a process subject to so many variable influences. Certain theoretical considerations have been developed which seemed to bring order in this chaos. At present, however, we are less confident in the discovery of the general applicability of the theory, first formulated by Justus van Liebig in 1853 as the "Law of the Minimum". This great chemist, in studying the relation between yield of an agricultural plant and nutrient mineral (N1) added showed that the yield curve (yield as a function of added nutrient) is a straight line, which shows at a certain value of nutrient added, a sharp discontinuity, after which it becomes parallel to the abscissa. Beyond a certain concentration, the nutrient is no longer effective. According to Liebig, another nutrient has become the "minimum factor" and addition of this new nutrient (N2) will again increase the yield until it is no longer effective.
> [….]
> Similarly, we may conceive of a kinetic analogue, articles prepared by subsequent manipulations on an endless belt. Here the slowest manipulation determines the yield. De Vries (1939) cites cases in which "Liebigian" yield curves have actually been obtained in agricultural experimentation (chiefly in pot experiments). Blackman, as a result of his experiments on leaves (Blackman, 1905) reached a similar conclusion for the factors influencing photosynthesis; temperature, light intensity and carbon dioxide tension.
> […]
> It was soon found that the "minimum" factor, in yield studies, is of greater influence if the other "production factors" are optimal. This means that the "pitch" of the curve will vary according to the nutritional condition of the plant and that also the maximal yield should be attained at a different rate. Mitscherlich (1931), while granting that a certain production factor is influenced by the level of the other production factors, claimed that the production factor studied will (independent of the others) always cause a fixed percentage of the maximum yield. This would mean that, let us say, the points indicating a given yield will have the same abscissa.

Eilhard Alfred Mitscherlich (1874-1956), German agriculturist. Mitscherlich's most important scientific achievement the law of effect of growth factors. In contrast to the law of the minimum established by Justus von Liebig, according to which, of all mineral nutrients, those that are present in the smallest amount in the soil determine the plant yield decisively, Mitscherlich demonstrated that the yield level depends on all growth factors. According to his research results, each individual growth factor can increase the level of income with a specific intensity (effect factor). However, as you approach the maximum yield, the additional yield becomes significantly lower due to a further increase in a certain growth factor compared to the expenditure.

111 Reference to Blackman (1905).

112 Clarke (1916) took Table 3.5 from R. Müller (1877, Table p. 39). According to Clarke (1916), "Müller gives a good summary of previous work upon the subject."

1. *Undecomposed dionite Albemarle co Virginia*
2. *do, decomposed*
3. *Laterite (dionite) Seychelles*
4. *90% kaolinite, 10% montronite*
5. *100% kaolinite * $H_4Al_2Si_2O_9$, or $Al_2O_32SiO_22H_2O$*
6. *100% montronite $H_4Fe_2SiO_9$, or Fe_2O_3, $2SiO_2$, $2H_2O$*
7. *Bauxite (Clarke [1916], p. 490) (94% Al_2O_3).*
8. *Average of 5 river sands (Clarke [1916], p. 499).*
9. *Rhine silt, Lake of Constance, practically as 8.*

* *Modern ideas are that rather, at physiological temperatures Montmorillonite is found, which is a Ca, Mg, Al silicate.*

1-2-3-7 more usual in the tropics (?).

%	1	2	3	4	8
SiO_2	57.5	48.7	6.7	52.8	87.2
Al_2O_3	21.7	29.5	66.1	40.2	9.7
Fe_2O_3	20.8	21.8	27.2	7.0	3.1

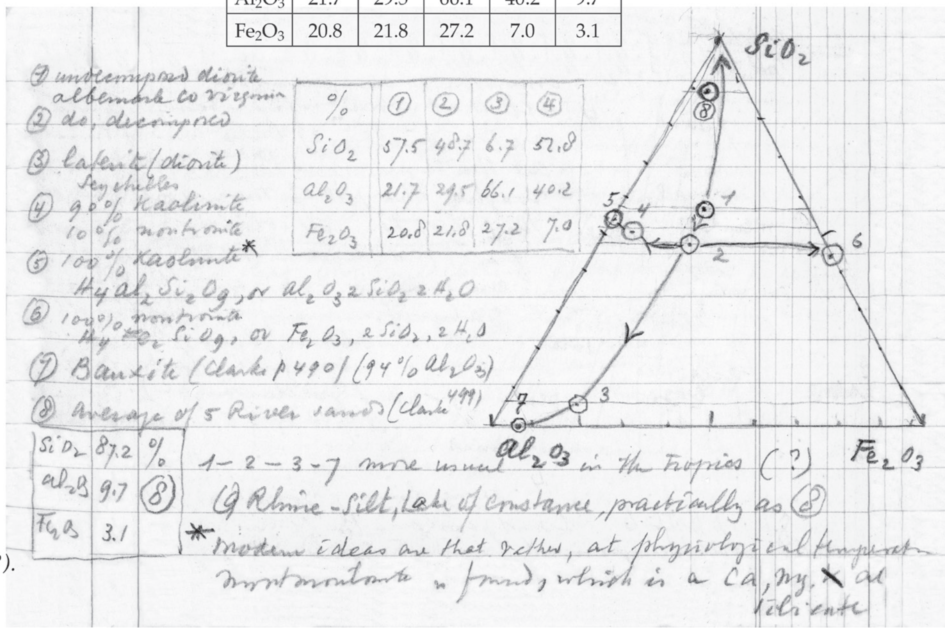


Figure 3.19 Equilateral triangular plot with compounds of SiO_2 – Al_2O_3 – Fe_2O_3. 1. Undecomposed dionite Albemarle Co, Virginia; 2. Ditto, decomposed; 3. Laterite (dionite) Seychelles; 4. 90 % kaolinite, 10 % nontronite; 5. 100 % kaolinite* $H_4Al_2Si_2O_9$, or $Al_2O_32SiO_22H_2O$; 6. 100 % nontronite $H_4Fe_2SiO_9$, or $Fe_2O_3.2SiO_2.2H_2O$; 7. Bauxite (Clarke, 1916, p. 490) 94 %Al_2O_3; 8. Average of 5 river sands (Clarke, 1916, p. 499); 9. Rhine silt, Lake of Constance, practically as 8.

* Modern ideas are that rather, at physiological temperatures montmorillonite is found, which is a Ca, Mg, Al silicate.

In clay we find only kaolinite $Al_2O_{32}SiO_2.2H_2O$, but also, and even more frequently, montmorillonite Al_2O_3 $4SiO_2.2$ H_2O, also containing Mg and Ca. Montmorillonite is able to swell. Halloysite is Al_2O_3 $2SiO_2.4H_2O$. These minerals are found in clay, they are found from feldspars, quartz, mica. Furthermore, we find the biogenic admixtures such as lime, silica and organic substances. Further, in the sediment there are found secondary minerals such as FeS, FeS_2, glauconite. Due to the small pore volume of the clay (the air place has to be considered more fully), biological influences may be much greater here (anaerobiosis) than in sand. The weathered clay minerals are capable of *base* exchange; they may exchange NH_4^+ in the outer solution for another cation:

Kaoline	15	
Mica	20	Mg/acq.
Montmorillonite	50-100	

3.4 % K_2O exchanged in montmorillonite! However, humus has even a higher exchange capacity!

3.12.3 Types of soil

Taking sand and silt as one, we may represent by a three component diagram the types of soil that interest us (Fig. 3.20). The components are

1) sand/ silt,

2) lime and

3) humus.

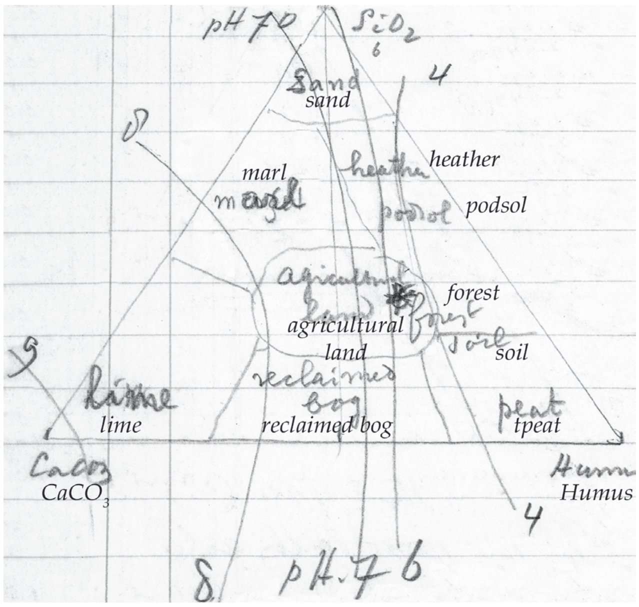


Figure 3.20 Equilateral triangular plot ("chemogram") with compounds of SiO_2 – $CaCO_3$ – Humus. The curved lines are varying pH values (pH = 4 to pH = 9). The ideal agricultural soil is represented by *. Sand, heather, podsol, marl, forest soil, lime, peat, agricultural land, reclaimed bog are shown.

At the same time the diagram gives roughly the pH of these soils (*id est* the pH of the soil solution), an important fact, in as much as most plants are sensitive to pH and the optimum range for many agricultural plants have been carefully determined (Goedewaagen).[113] From a pH of 3.5 in peat (see Section 2.4.8, Table 2.12) we range to a pH 9 in the pure lime. Good agricultural land contains the three components but still ranges in pH from 5.5-8. Studies "Kalkzustand".

A humus percentage and a mechanical analysis might, therefore, in principle, characterise a soil. On acid soils we get inevitably, a leaching out of the mineral matter, especially of the metals. The soil *podsolises*,[114] and usually the humus substance dissolved forms again a layer of hardpan, spoiling the physical structure. The ideal agricultural soil should have a high humus content and a pH a little below 6. It is represented by * in the diagram (chemogram; Fig. 3.20) (included here from table of Goedewaagen for pH and agricultural crops). Here below are given typical plant communities for the different types of soil (Russell).[115] Humus is the cause of the CO_2 production of soils (Hesselink van Suchtelen),[116] alkali soils (black alkali) contain $NaHCO_3$ and Na_2 CO_3.

In Figure 3.20, the laterite soils and the clay are not mentioned. Of course, the symbol SiO_2 has to represent bauxite, montmorillonite, kaolinite, laterite and quartz. These minerals however, do not influence actual acidity as much as the humus, which is an active generator of H^+ ions by exchange, as demonstrated in Section 6.3.4 of this book.

Humus. (Waksman, Naumann, Russell) Humus is a complex of plant and animal remains, partly mineralised, carbonised and caramelised, together with a living flora and fauna, consisting of bacteria, fungi, algae, protozoa, nematods, insects and crustacean, and their recretions, excretions and secretions and this complex is superimposed upon a mineral matrix. The organic and mineral matrix are both partly or fully saturated with capillary and colloidal waters. This complex, it stands to reason cannot be initiated by chemical or physical treatment of simple substances, as has often been attempted. From the data of geochemistry (Clarke, 1916) where several analyses of rock decomposition are given, it is known that with this decomposition the organic contents increase. It has often been assumed that the "metabolism" of the humus is so intense in tropical climates, that no accumulation occurs. Dr. Hardon, however found 5 % organic substance in a yellow Java lawn (oral communication).[117] It is true that in the tropics leaf mould does not accumulate with the same intensity as in moderate climates, except where the pH is sufficiently low (the so called Borneo padango, for instance). Before the times of Justus von Liebig, it was assumed that plants needed this humus for their development. Liebig is the author of the mineral theory which, in a general form, still expresses the consensus of opinion. The virtue of stable manure or of "night soil" (China) was ascribed solely to the improvement of the soil structure and of the minerals contributed by the manure. A commercial fertiliser (guano excepted) used in enormous quantities, expresses the universal belief in the mineral theory. However, there are valid reasons to doubt the rigorous validity of this hypothesis in view of the fact, expressed at so many places in this essay, that plants are hardly ever dependent on other organisms. That nutrilites, or ergones, organic substances active in small or very small concentrations, might be as necessary for plant life as the mineral minimum elements! The manufacture of compost by biological means and with the use of a great many components might therefore yield an organic substrate immensely rich in ergones. Now it appears that excrements are particularly rich in ergones. The humus theory may be said to be revived. The mineral theory has been necessary to emphasise the fundamental facts of plant physiology. But the "ideal" plant, the organism totally independent of the organic environment, unfortunately rarely exists. "In principle", plants are mineral feeders, synthesising their own organic matrix, but in practice they need more organic, than in organic minimum substances, the majority of which are, however, still unknown.

3.12.4 Properties of soil, particle size

For our purpose a rough classification into clay, silt and sand, suffices, and a characterisation in a simple triangle is all that is needed. Of course, the transitions between the three concepts are gradual, and therefore Figure 3.21, as used by Correns (1939), is to be preferred.

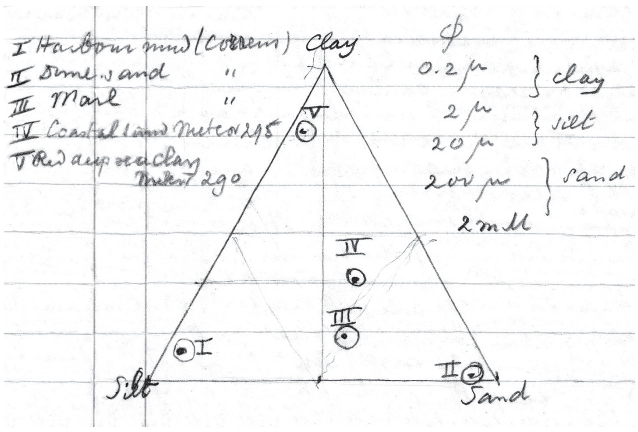


Figure 3.21 Equilateral triangular plot with compounds of clay, silt and sand. I. Harbour mud (Correns, 1939); II. Dune sand (Correns, 1939); III. Marl (Correns, 1939); IV. Coastal sand (*Meteor*, p. 295); V. Red deep sea clay (Mi., p. 290). ϕ diameter: 0.2 μ – 2 μ clay; 2 μ – 20 μ silt; 20 μ-200 μ- 2 mm sand.

A clay, due to the fine nature of its particles, but also due to the open laminar structure of its components, will have little air space. Aeration is difficult, which is important for many plants. Tobacco roots require, for instance, a highly aerated soil (Van der Wey, 1932), while there are other plants (rice, willow, water lily) which may live in almost anaerobic conditions.[118] Clay induces anaerobiosis. Sulphate reduction sets in lastly.

113 Matthijs Arnoldus Jan Goedewaagen, PhD Utrecht 1933, *De Invloed van de Nitraatconcentratie der Voedingsoplossing op den Groei van Tarweplanten*, supervisor F.A.F.C. Went. Baas Becking referred to Goedewaagen (1941).

114 Podsolisation is a complex soil formation process by which dissolved organic matter and ions of iron and aluminum, released through weathering of various minerals, form organo-mineral complexes (chelates) and are moved from the upper parts of the soil profile and deposit in the deeper parts of soil.

115 Reference Russell and Russell (1912), *Soil Conditions and Plant Growth.* See also Section 1.2.3.b.

116 Hesselink van Suchtelen (1923), Energetik und Mikrobiologie des Bodens.

117 Reference to Dr. H.J. Hardon, agricultural experimental station Buitenzorg Java, he published about the mineralogy of clay in Java in the 1930s.

118 Reference to Hotze Gysbert van der Wey, who defended his PhD thesis *Der Mechanismus des Wuchsstofftransportes*, in 1932 in Utrecht. Supervisor F.A.F.C. Went. In the 1930 and 1940s van der Wey did research on the mosaic problem in tobacco cultures and the relationship between soil type and mosaic, in Medan, Sumatra, at the Deli tobacco culture station.

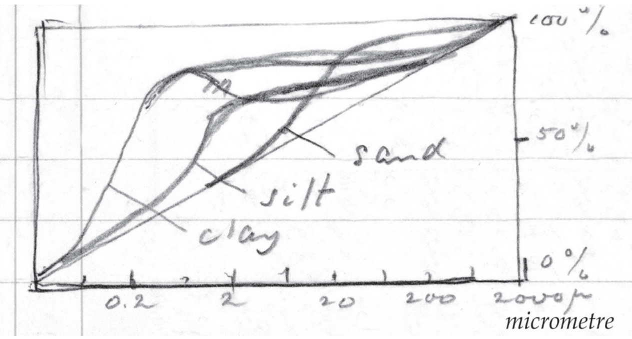


Figure 3.22 Schematic representation of the total line. Showing: 1. only grain size of 10 mm; 2. all grain sizes are equally represented; 3. little fine, much coarse material; 4. a lot of fine, little coarse material; 5. maximum with a grain size of 4 mm; 6. maximum at 2 and 6 mm, minimum at 4 mm. After Correns (1939, p. 150).

Correns (1939) has made use of a method which shows the composition of a certain soil quite clearly (Fig. 3.22). If one plots particle size on the abscissa, frequency (summated) on the ordinate, a soil which shows an even distribution of all fractions may be represented by a straight line. If there is a preponderance of a certain range of particle sizes, it will show as a "humus" in the curve. In this way, by integrating, we evade errors due to class size.

Soil in relation to water (see Russell and Russell, 1912),[119] requires special treatment. Here the water holding capacity depends not only upon the size and shape of the interstice, but also upon the swelling of the soil colloids. It is important to note that montmorillonite is highly swellable. A soil may hold water still in dispersed condition (the soil particles being continuous) while mechanical shaking will cause the phase to revert (thixotrophy). This is particularly striking in sea sand (drifting sand).

3.12.5 Base exchange, zeolite action

The composition of the air in soil is variable. Roughly the CO_2 contents goes in parallel with the humus percentage. In the original rock very curious gases occur, as Table 3.6, taken from Clarke (1916, p. 272), shows. [The composition of soil is summarised in Table 3.7.]

Table 3.6 Percentage of gases extracted from granite of Vire. From Clarke (1916).

CO_2	14.42	CH_4	1.99
H_2S	0.69	H_2	76.80
CO	5.50	N_2 (??)	0.4
Volume *per* kg rock (heated) 2709 However, probably generalised by chemical reactions (red heat) from granite.			

If the soil is well aerated, *Azotobacter* may function as a nitrogen fixing agent. In anaerobic soils *Closteridium* is active (see Section 6.4.2.a). Oxygen is, of course, variable. Hydrogen may be generated by cellulose fermentation and other fermentations. Hydrogen sulphide by sulphate reduction (or, as a *secondary* factor by "putrefaction of proteins"). It may be highly toxic to plants. Free ammonia only occurs in highly basic soils on the further composition of the soil solution. A soil without microbes, it should be stated, is a dead soil. The role of the organisms in the soil is still very imperfectly known. The contribution of *ergones* seems to be one of the chief acts (see Section 7.2, *Ergones*).

Table 3.7 Composition of soil.

Phase	Composition of soil	
I Gaseous	Oxygen, nitrogen, CO_2, H_2S, NH_3, hydrogen. Volatile compounds	
II Liquid	Water, gases as in I, but also dissociation products of H_2CO_3, H_2S, NH_3 Inorganic, like SO_4^{2-}, Cl^-, PO_4^{3-}, $H_2PO_4^-$, K, Mg, Na, Ca, Al, Fe Organic e.g,. humic acid, organic CO_2 and, especially ergones	
III Solid	Mineral e.g., feldspar, quartz, kaolinite, montmorillonite, laterite, lime in various sizes and shapes Organic e.g., substances in the process of carbonisation and caramelisation digestible like chitin and substances in the carbon cycle	
IV Biotic	Plants Bacteria, moulds, algae, Eumycetes, mosses	Animals Protozoa, Nematods, Rotifers, Tardigrades, Earworms, Mites, Spiders, Crustacea, Insects, Millipedes

3.12.6 Summary and conclusions

[Baas Becking left this section blank.]

3.13 Water, Hydrobiosphere

3.13.1 Introduction

[Baas Becking left this section blank.]

3.13.2 Rain

[Baas Becking inserted Table 3.8, taken from Clarke (1916).]

Table 3.8 Comparison of air in rainwater. From Clarke (1916).

	0°	5°	10°	15°	20°
N_2	63.20	63.35	63.49	63.62	63.69 %
O_2	33.88	33.97	34.05	34.12	34.17 %
CO_2	2.92	2.68	2.46	2.26	2.14 %

16 mg/L HNO_3, 4 mg/L NH_3 (Caracas, Venezuela), rain contributes up to 75 kg/Ha in salts. An analysis of rainwater from Wyster, Drenthe is given below. See Figure 3.23 [Sulphate reduction].

3.13.3 Freshwater

[Baas Becking inserted Fig. 3.24, a triangular plot of 15 waters of unusual composition].

See Figure 5.14 and Figure 6.3, Section 6.4.3.

119 Russell and Russell (1912), *Soil Conditions and Plant Growth*.

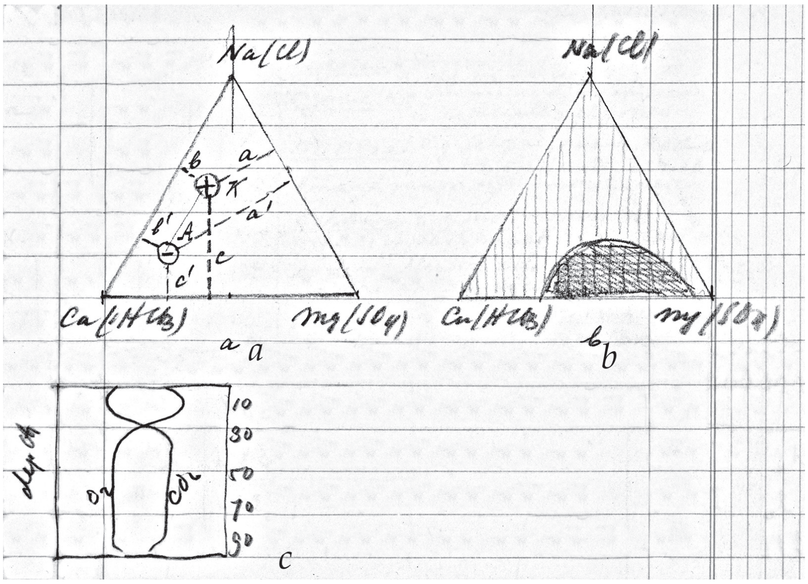


Figure 3.23 Equilateral triangular plot with compounds Na(Cl) –Ca(HCO_3) – Mg(SO_4). In 3.23a (+) K represents cations a: b: c = Ca^{2+}: Mg^{2+}: Na+; (-) A represents anions a': b': c' = HCO_3-: SO_4^{2-}: Cl-. In Figure 3.23b the dark shaded apart represents the "forbidden area". Figure 3.23c gives the depth distribution of O_2 and CO_2 in freshwater.

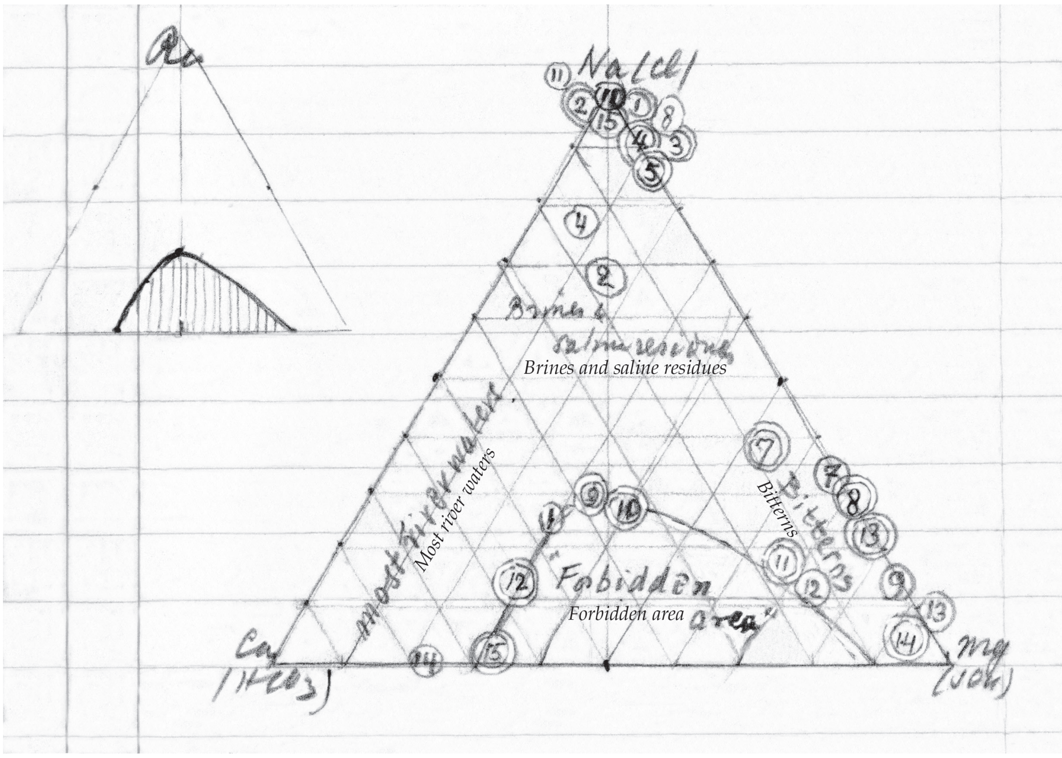


Figure 3.24 Equilateral triangular plot with compounds Na(Cl) – Ca(HCO_3) – Mg(SO_4) of 15 waters of unusual composition in percentage equivalents, to outline the so called forbidden area (data recalculated from Clarke (1916). ◎ ration cations; ○ ratio of anions.

Plotted are: Brines and saline residues, Most river waters, Bitterns, Forbidden area.

Numbers refer to lakes: 1. Lasarnie Lake [?]; 2. Soda Lake, Nevada; 3. Spring near Abilene, Kansas; 4. Pyramide Lake, Nevada; 5. Serier Lake; 6. Red Lake, Perekop; 7. King's Springs, Dallas Texas; 8. Elton Lake, Russia; 9. Chicken Kanab, Yucatan; 10. Bittern, Syracuse, N.Y.; 11. Dead Sea, 20 m deep; 12. Utah Lake; 13. Spring at Cruzy, France; 14. Pine Creek, British Columbia; 15. Bittern, Pomeroy, Ohio.

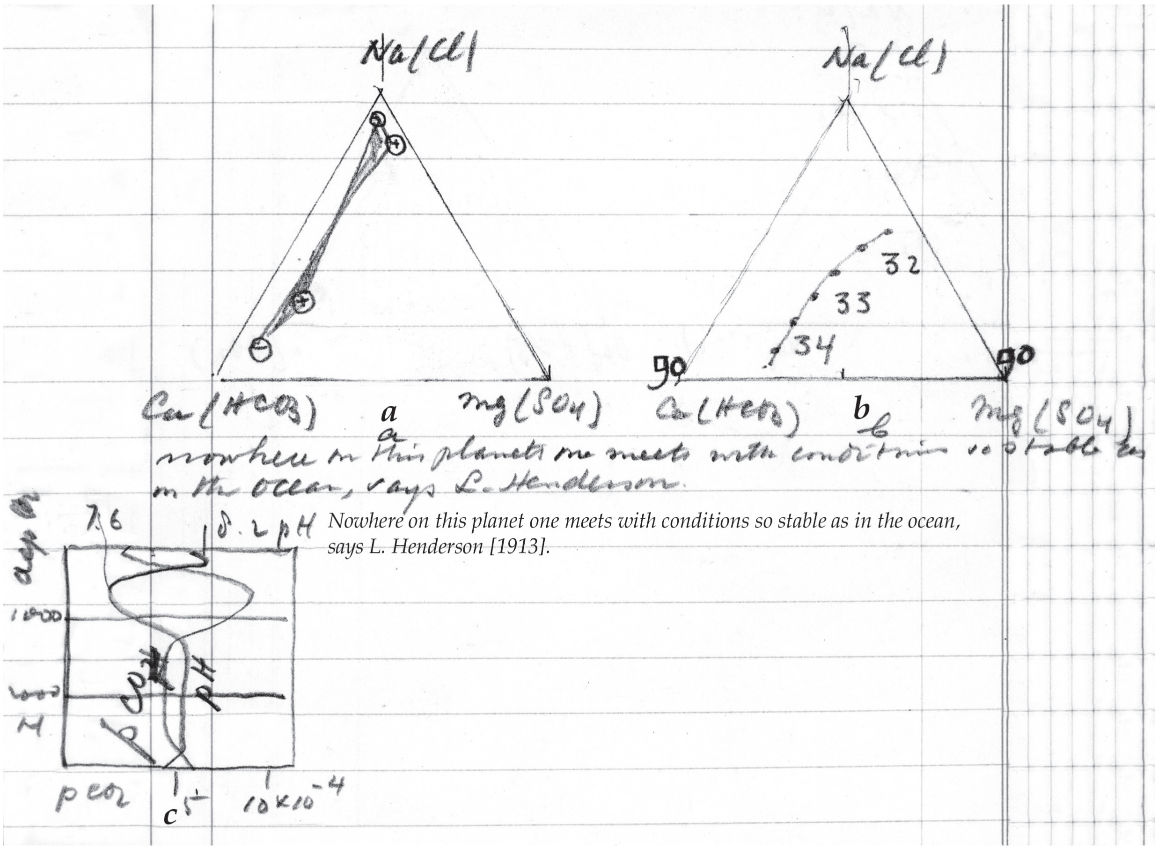


Figure 3.25 **(a)** Equilateral triangular plot with compounds Na(Cl) - Ca(HCO_3) – Mg(SO_4) of river water (low calcium and carbonate) and seawater (high calcium and carbonate): (+) ratio cations and (-) ratio anions. **(b)** Equilateral triangular plot of seawater with compounds Na(Cl) - Ca(HCO_3) – Mg(SO_4) above percentages of 90 % NaCl. **(c)** Depth distribution of pH and pCO_2 in ocean.

Knudsen S = 0.030 + 1.8050 Cl %.[120]

3.13.4 Ocean water

See also Section 6.4.3, *Changes in the hydrosphere* and Section 5.7.6, *Natural waters again*.

[Baas Becking inserted Fig. 3.25, copied from *Geobiologie,* 1934; Fig. X.1 in Baas Becking, 2016.]

Nowhere on this planet one meets with conditions so stable as in the ocean, says L. Henderson.[121]

3.13.5 Brines

[Baas Becking inserted Fig. 3.26.]

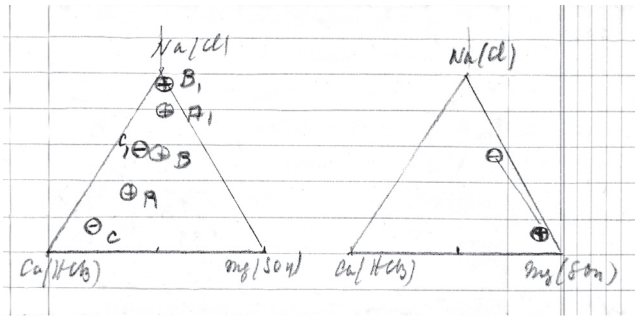


Figure 3.26 Equilateral triangular plot of brines with compounds Na(Cl) - Ca(HCO_3) – Mg(SO4), with anions (-) and cations (+) in % equivalents. (a) Three types of brines. (b) Type of bittern.

120 Reference to the Danish physicist Martin Hans Christian Knudsen (1871-1949). Knudsen was also active in physical oceanography, developing methods of defining properties of seawater.
Baas Becking gave the relation between Salinity (S) and Chlorinity (Cl) that Knudsen published in 1901 as S = 0.03 + 1.805 Cl. In the 1953 version of *Geobiology* (Baas Becking, 1953a), he referred to the Knudsen relation (p. 322):

> An empirical relation between the total solids and chlorinity was derived by Knudsen: S % = 0.030 + 1.8050 Cl %. This relation, however, only applies to seawater diluted with rain or feebly concentrated by solar heat. Deviations from Knudsen's equation occur when river water is mixed with seawater.

See Lyman (1969), Knudsen (1901). I thank Dr. Ir. Laurène Bouaziz (Delft) for the reference to Lyman and Knudsen.
In his lecture during the Sixth International Botanical Congress in Amsterdam in September 1935, Baas Becking (1936a) remarked that the Knudsen relation "cannot be applied to the brackish waters of the [freshening] Zuyderzee":

> If North Sea water is diluted with distilled water (comparable to the extremely pure Swedish and Russian rivers, which empty into the Baltic), Knudsen's equation does not apply, but the rather high amount of dissolved salts in the Netherland's river water, such as Yssel water, exert a marked influence upon the composition of the mixture.

Baas Becking referred to the Dutch research on the chemical and biological processes of freshening of the water of the former brackish inland Zuiderzee since the closure of the 32 km long Afsluitdam in 1929.

> Not only a process of dilution, a considerable shift in the ionic proportions may occur and, consequently, the antagonistic action of ions is greatly changed. My own experiments upon euryhalinic organisms have convinced me that the shift in ionic proportions is as important as the decrease in osmotic pressure – the differences in the plankton of the Baltic and the former Zuiderzee may be, at least partially, accounted for by this fact.

121 Baas Becking referred to Chapter V in Henderson (1913):

> Certainly, nowhere else where life is possible, probably in no other place in the universe except another ocean, are so many conditions so stable and so enduring (p. 186, edition 1970).

3.13.6 Soil solution

[Baas Becking left this section blank.]

3.13.7 Dystrophic waters

[Baas Becking left this section blank.]

3.13.8 Physical factors, temperature, thermocline etc

[Baas Becking inserted Fig. 3.27.]

3.13.9 Summary and conclusions

[Baas Becking left this section blank.]

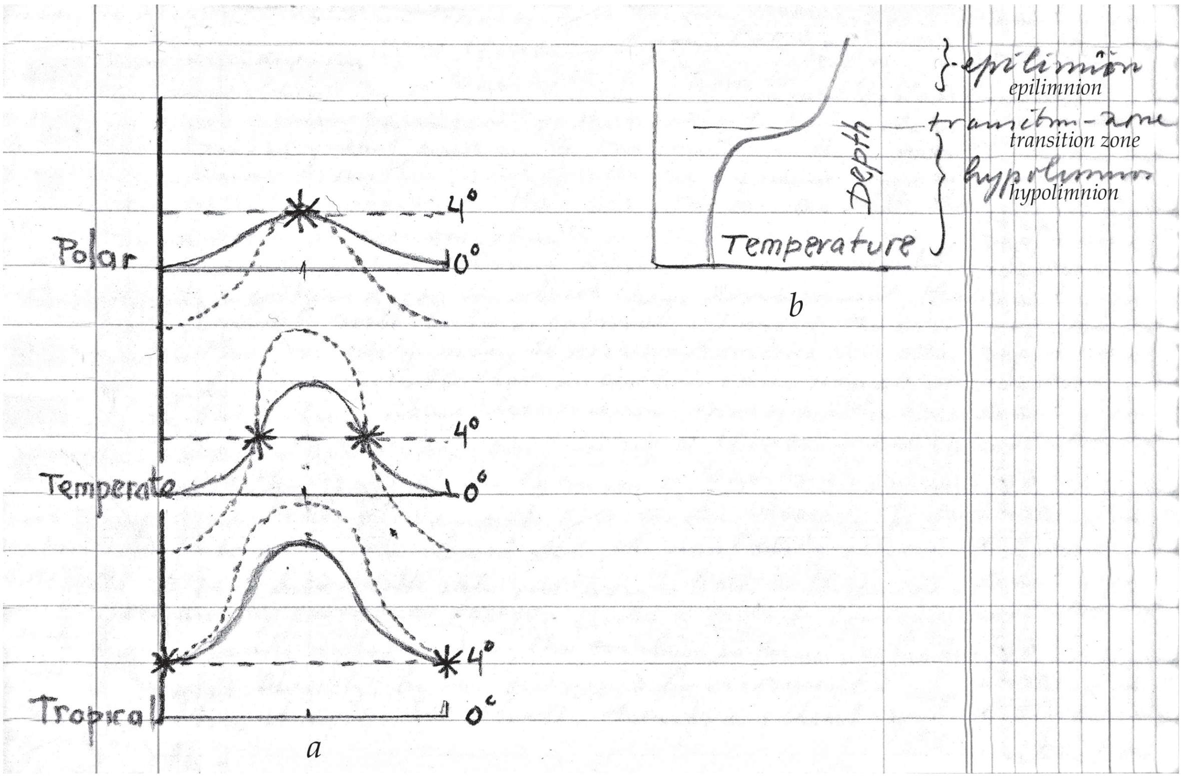


Figure 3.27 **(a)** Thermoclines (depth *versus* temperature) based on season and latitude. **(b)** Temperature profile *versus* depth, showing epilimnion, transition zone and hypolimnion.

4. THE ORGANISMS

4.1 Nature of Living Matter, '*Elan Vital*'

4.1.1 Introduction

If we consider the milieu as the stage of the life drama (Lotka), the living beings are the actors and the drama consists, like any proper 'roman familial', "of the relation between these actors with their environment and with another."[1] If we want to consider living things from this point of view, we are much more concerned with their activities and with their composition as with their form. Our problem is, therefore, chiefly a physiological one. Most living beings have, somewhere in this milieu, a certain area in which their development, their increase, their general well being is optimal. Toward the limits of the milieu this "vitality" may be decreased or lead into other vegetative channels. It is probable that in certain cases sexual reproduction is all but a luxuriance phenomenon. Many are the cases described in the literature where copious fruiting or flowering are immediately preceded the death of the organism in question. In order to obtain large quantities of variants of a given species, the birth rate, the natality, should be high; the death rate, the mortality should be lowest. Birth rate and death rate, although both influenced by internal as well as by external factors, show a certain contrast; natality being chiefly influenced by the milieu interne, while the mortality is shaped chiefly by the outward environment. In this section we shall therefore, deal with population growth.

4.1.2 Method of increase

We have growth, we have vegetative and sexual reproduction. In any case, there is increase in living mass. Behind this increase there appears a blind driving force, a veritable life force, an 'élan vital'. This force of course has nothing in common but the name with its physical counterpart, but it is an enormous urge which presses every living thing to procreate, to make more of its self sameness, as if its specific protoplasm were the very salt of the earth, and the only species worthy to fill the earth. Give any organism its chance, and it will push all others aside. Any person with imagination shudders when he sees the amorphous masses of yeast cultured from a few cells in a few hours in the brewery, and our urge, to fill the earth with man, seems much less divine and less human than it was before, may be our deepest protoplasmic urge, which we have in common with all other living creatures.[2]

4.1.3 Laws of increase

We shall have occasion later to revert to the problem of population curves (Section 5.1, *Growth Curve*). In the majority of cases in time x there is an S-shaped increase in the population y, which reaches a saturation level *a* (Fig. 4.1). This has been represented (arbitrarily as we shall see) by many authors as

$$y = \frac{a}{(1 + e^{-bx})}$$

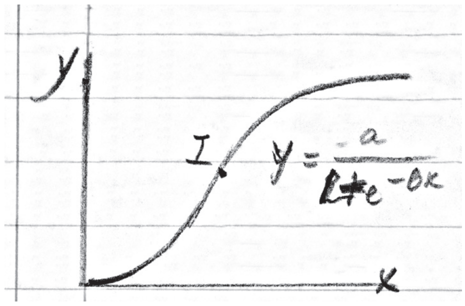


Figure 4.1 S-shaped growth curve.

The first phase, before the inflection point I is reached, is called the logarithmic phase (especially by bacteriologists), and it is this phase often preceded by a lag phase, that often represents growth. This may be represented by a simple e function or a parabola, often of higher degree.

In the above equation the point of inflection at x = 0 is symmetrical at y = a/2. However, in practice the first, or the second point of the curve may be the shortest. Moreover, after reaching the limit *a*, there may be superposition of new S-curves, or there may be a decrease. We shall see later that the growth of a filamentous algae, or of unicellulars in which the milieu is kept constant, often follows a curious law; a series of S-curves which, together, are situated on a parabola (Fig. 4.2). For epidemiology the shape of such curves is of great importance. It often looks like the figure below (Fig. 4.3). The section on population statistics the matter shall be dealt with more in full.[3]

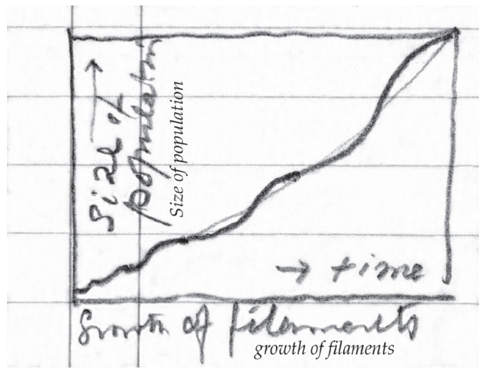


Figure 4.2 Series of S-shaped growth curves, growth of filaments. Y axis: Size of population; X axis: time.

1 Lotka (1924), Chapter XV, *The Stage of the Life Drama*, p. 185-209:
For the drama of life is like a puppet show in which stage, scenery, actors and all are made of the same stuff. The players, indeed, 'have their exits and their entrances,' but the exit is by way of translation into the substance of the stage; and each entrance is a transformation scene. So stage and players are bound together in the close partnership of an intimate comedy; and if we would catch the spirit of the piece, our attention must not all be absorbed in the characters alone, but must be extended also to the scene, of which they are born, or on which they play their part, and with which, in a little while, they merge again.

2 In the unfinished manuscript *The Kingdom of this World* (Baas Becking,1942-1943) remarked (p. 20):
What the press and literature calls, "deepest human feelings", "humanity" *etc*., is often nothing but reference to factors promoting the increase or maintenance of the existing living human mass. It is the deepest instinct, it is the protoplasmic instinct, common to all living beings. Every species of living thing behaves as if it should want to fill the earth to overflowing, and it had the chance. A feeling, which is almost fear, mastered me once when I visited a brewery and saw how the microscopic yeast plant could multiply in a few days to enormous, amorphous masses.

3 Shortly after WWII Baas Becking presented a paper (August 19, 1945), *On the Analysis of Sigmoid Curves*, that was published in 1946 in *Acta Biotheoretica*. (Baas Becking, 1946a). See also Section 5.1.1.

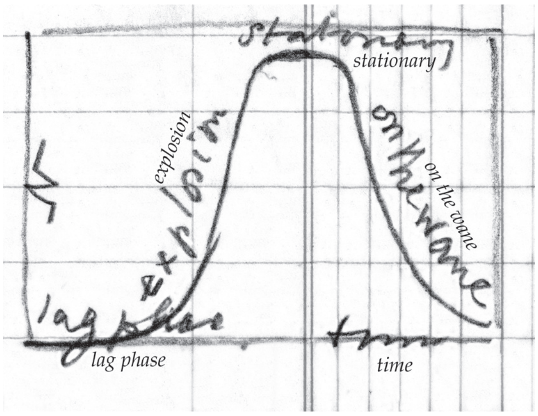


Figure 4.3 Example of epidemiological curve (size of population N against time) with phases: lag time, explosion, stationary, on the wane.

4.1.4 Census of populations (e.g., birds)

L. Tinbergen has given a census of our common Holland birds.[4] It appears that their numbers are to all intents and purposes, stationary. Mortality and natality keeping each other in check. The population curve would probably look somewhat like in Figure 4.4.

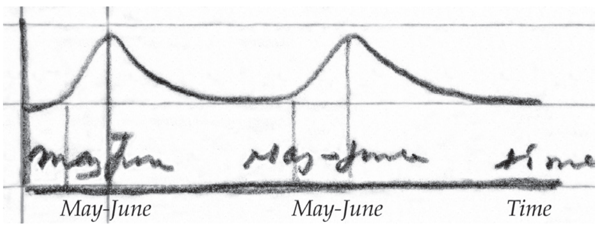


Figure 4.4 Seasonal increase and decrease of a bird population, peaks in numbers May/June (after Tinbergen, 1946).

From the literature we should cull data on 1) species, 2) species periodically reduced to one individual (in winter), and 3) species subject to "vital explosions" (Lotka?).[5] This section should be elaborated. In laboratory populations (bacteria), we usually obtain increase curves of the following shape (y axis, *Bacillus megaterium*). Here secondary and tertiary masses appear (Fig. 4.5). The whole phenomenon is highly influenced by milieu.

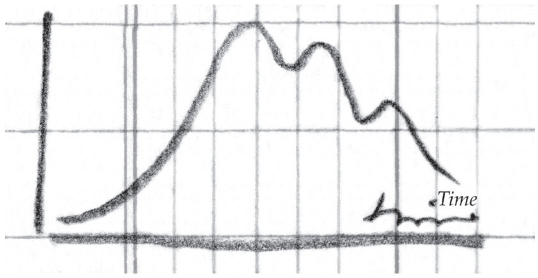


Figure 4.5 Example of the increase and decrease curve for a laboratory population of *Bacillus megaterium*.

4.1.5 Natural sequence

A sequence (see Section 7.8, *Cycles*) may either involve the life cycle of one organism or of several. In the first case the culture may show considerable "lag" (Pasteur effect, mildew in yeast) then a logarithmic phase sets in. Somewhere in this phase (as in the case of *Chlamydomonas*) substances ar[illegible]xual activity, and so the culture wi[illegible]opmental phase. It makes its own "necrosymbiotic" milieu.[6] If other organisms enter in (the case is even more complicated), their influence, adverse or beneficial, belongs to the external milieu (see Section 4.5) and is, like the "necrosymbiosis" chiefly chemical. On totally sterile soil, perfectly mineral, we have to expect first a perfect, nitrogen fixing, autotroph, to be followed by these organisms that are less independent. In the case of epidemics (Sections 5.10 and 7.5) the epiparasite and the phage may come in as a natural brake.

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4 Reference to Luc Tinbergen (1915-1955). Baas Becking knew Tinbergen's research of bird populations in The Netherlands, that was published in 1946 after the War as a PhD thesis, *De Sperwer als Roofvijand van Zangvogels*. Leiden, Brill. In the 1953 version of *Geobiology* (Baas Becking, 1953a), he referred to Tinbergen (p. 123-124):

> Populations of sparrows (Tinbergen, 1946) and of seasonal plankton fluctuate between two extreme values. If the minimum population value is transgressed, the population becomes extinct, while of the exponential phase is enhanced by environmental conditions, we may witness a temporary dominance, often of an epidemic nature which is called an "explosion" by Vernadsky (1924).

See also Gibb (2008).

5 Baas Becking referred to Lotka (1924, p. 13) where the term 'Vital force', as used by biologists, is critically discussed in favour of the approach of the physicist:

> He the physicist discovers that a quantity ½ mv^2 possesses certain important properties. *Then*, he proceeds to name it: *Energy*, in particular, *kinetic energy*. But biologists have been disposed sometimes to adopt the reverse procedure: they have named a *vital force*, a *nerve energy*, a mental energy, and what not, and now they entertain the pious hope that in due time they may discover these "things."

In the 1953 version of *Geobiology* Baas Becking referred on p. 648 to the Lotka-Volterra equations:

> Due to Lotka-Volterra oscillations (in both relative and absolute masses of components in a biocoenoses) we cannot sharply define any state in a succession. These oscillations may become so violent that one or more components of the biocoenosis will be 'shot off at a tangent.' Vital explosions, and epidemics may be the result. The succession in its integrated form is one of the highest forms of expression of the bioecenosis. The concept has been, maybe unconsciously, applied by historians so that, according to some (*e.g.*, Spengler) an overhanging doom makes the earth "a checkerboard of nights and days, where destiny with Man for pieces plays." In view of the great prospective potencies of mankind such conclusions seem contrary to reason. Rhythms of an even longer wavelength may find expression in the earth's history. These are the rhythms of evolution.

6 See also Section 7.2.11.

4.1.6 Equilibrium conditions

Equilibrium conditions are of the nature of the stationary state (or "harmony" as it is called by my fellow country man J. Straub).[7] This is a condition in which the "same" is maintained by a continuous change, like the shape of a water jet from a faucet. Now in nature such a monotonous pressure is never realised. There is a "drift" in the equilibrium, in the stationary state. This drift is not undisturbed, it appears as a life cycle, as a biocoenotic cycle, it is recurrent. Lao Tze has said: "One engendered many, many engendered millions - and a million things return to one." Still, apparently constant conditions may be obtained in laboratory cultures, although we should never forget the diction of Winogradsky, that we are working, in this case, with 'circus animals.'

4.1.7 List of organisms of geochemical importance

(This to be elaborated to a separate section, with plates and descriptions).

Table 4.1 List of organisms of geochemical importance.

Bacteria	Protozoa	Mollusca	Fishes	Plants
1 Purples	1.Amoeba	1.Gasteropods	1.Chanos	1.Polyblepharids and
2 Sulphate reductors	2.Ciliates	2.Bivalves	2.Shark	Euglena, …
3 Closteridia	3.Flagellates	3.Boring mussels	3.Eel	2.Green algae
4 Aerobic Sulphur	4.Foraminaf[era]	**Crustaceans**	4.Haplochromids	3. Brown algae
5 Nitrobacter	**Rotifers**	1.Asteridium	5.Cod	4. Bluegreen algae
6 Nitrobacterium	1.Brachium	2.Coppepods	6.Herring	5.Fungi, Equisetum
7 Urobacter	**Bryozoa**	3.Ostracods	7.Gasterosteidae	6.Mosses and ferns
8 Cellulose bacteria	**Sponges**	4.Daphnids	8.Gobio	7.Corallines
9 Methane	**Sea anemones**	5.Cra…	**Reptiles**	**Trees**
10 Hydrogen	**Corals**	6.Crabs	**Amphibia**	
11 Carbon peroxide	**Echinoderms**	7.Crayfish	**Aves**	
12 Oil and bitumen	**Worms**	8. H..	excrements	
13 Halophilic	1.Arenicola	9.Trilobites	**Mammals**	This is one of the most important parts of the book, but cannot be elaborated here!
14 N fixation	2.Nereis	**Insects**	1.Cow	
15 Nitrate reduction	3…	1.Hymenoptera	2. Koala	
16 Carbon organisms	4.Serpula	2.Hydr..	3.	
17 Thiosulphate	5…	3.Spiders	4.	
18 Iron bacteria		4…	Man	
19 B. proteus				
20 B. coli				

4.2 Chemical Composition

In 1898 Léo Erréra of Brussels published a memoir entitled *Pourquoi les Elements Vivants ont-ils des Composés Moléculaires Moins Elevés*.[8]

4.2.1 Relation between common and bioelements

[Baas Becking left this section blank.]

4.2.2 Analysis of plants

Nothing seems more variable than ash analysis of vegetables.

7 Baas Becking referred to Jan Straub (1888-1975), director Gemeentelijke Keuringsdienst van Waren in Amsterdam and Lector Keuring van voedingsmiddelen University Amsterdam (1946-1949). He probably was acquainted with Straub in the period 1942-1944 when he was working for Unilever. In the 1953 version of *Geobiology* (Baas Becking, 1953a), he referred to Straub's findings in section *The Nature of Living Beings* (p. 115-117).

The thermodynamics of reversible processes, the consideration of closed, cyclical, systems, has accounted for many biological phenomena. However, a living being cannot be considered as such a closed system of minimum free energy in which equilibrium reactions dominate the processes. Life is in constant interchange with its environment, as experiments with tracer elements have. shown (water, phosphorus, carbon, nitrogen). We are therefore in need of a more dynamical approach to describe vital processes. Hans Driesch (1921) [see also Section 5.8.2, *Teleology*] has described life as a "harmonic equipotential system", like a stream of water, of immanent shape but of variable composition. Heraclitus has stated that "nobody bathes twice in the same river." But the concept which has been most useful in the description of vital phenomena was given by Straub (1930 and 1933). This author could not account the ionic distribution between the white and the yolk in the hen's egg, which are separated by a thin membrane. Models, consisting of electrolyte solutions separated by an indifferent membrane (such as a porous pot) either under a chemical or under an electrical potential showed (Straub, 1933) that the ionic distribution could be accounted for if the system was actuated by an external source of material or of energy. Such a system was called by Straub a "harmony" and defined by him (1951) as "a stationary state of a mechanism or of an organism, maintained by constant exchange of matter, of energy, or both, with the· environment."

The text of the section is the same as the handwritten manuscript AAS 043 nr 90-3 in Canberra, which also contains a proof print of Straub (1951), *Over Abnormale Diffusie*. Baas Becking referred in the 1944 manuscript to Straub (1930) and Straub (1933).

The reference to Driesch (1921) not identified. Hans Driesch's "harmonic equipotential system" was first described by Driesch in 1899. For a review of 'vitalism in the early twentieth century' see Chen (2018).

8 Reference to Erréra (1886) *Pourquoi les éléments de la Matière Vivante ont-ils des Poids Atomiques peu élevés*? In 1887 translated in German in *Botanisches Zentralblatt*. Baas Becking referred to Leo Erréra's 'masterful treatise' in his inaugural address in Utrecht October 3, 1927, *Over de Algemeenheid van het Leven* [About the Universality of Life], that read in translation:

It is indeed curious to see how, in the periodic table of the elements, the actual "biogens" are collected in the three top series. Up to and including atomic number 20, the calcium, berylium and boron are exceptions. Does this mean, then, that the light elements are best suited for the manifestation of what we call Life, or does it simply express the fact that Life, as a vehicle, uses what was most obvious? That Life 'rows with the belts it has?' As Erréra puts it: "il faut remarquer d'abord que les substances rares, peu répandues à la surface du globe, ne pouvaient pas servir à l'entretien de la vie."

Baas Becking Archive Boerhaave Museum Leiden.

4.2.3 Analysis of animals

[Baas Becking left this section blank.]

4.2.4 Comparison of anomalous cases; accumulations by certain organisms

$Al(OH)_3$, accumulated by *Lycopods* and by *Symplocos* a tropical tree (family *Symplocaceae*) the extract of the leaves being used by the natives as a mordant.

SiO_2 in special cells (stegmata) of grasses, also in horse-tails. In the internodes of the bamboo in in porous like, very light masses, "tabashir." Further in radiolarian and diatom shells in sponge spicules

$CaCO_3$, *Moracaea* (Cystolith) and *Urticularia* in general. In the leaves of *Petraea* (*Verbenaceae*). In the walls of coralline algae (*Corallina*, *Amphiroa*, *Lithophyllium*, *Lithothamnion*) and green algae like *Halimeda*, freshwater algae like *Chara*. Also, calcite, aragonite, dolomite in many shells.[9]

Apatite $Ca_5F(PO_4)_3$, occurs in phosphate rock, in guano also $Ca_5Cl(PO_4)_3$. Further as calcite and Cu_3 $(PO_4)2CaCO_3$. H_2O, collophane $Ca_5(PO_4)2.5(CO_3)0.5(OH)$ and vivianite $Fe_3P_2O_8H_2$. Iodine and potash accumulate in sponges, in brown and in red algae. Bromine chiefly in red algae.

KH_2PO_4, accumulated as well as dissipated by every living cell. Excrement ("night-soil" of the Chinese) very much in KH_2PO_4.

4.2.5 Milieu externe and milieu interne

4.2.5.a Salt intake and excretion, secretion and recretion

We shall here only briefly outline the problem of intake and production of substances by living cells as part of the relation between milieu externe and milieu interne. The mechanism of the intake of substances is still obscure. Size of molecule, solubility in fat solvents and electric charge each playing a role. Moreover, the entrance of many substances in the cell requires energy ('das anionen phenomenon').[10] Arisz (1943) has analysed the mechanism of intake of various organic compounds.[11]

The substances entering may be given off again without change (Fig. 4.6). This we name *recretion*. A case in point is KH_2PO_4 (Loosjes, Lausberg) which is one of the most mobile substances both in animal and in plant physiology.[12] Furthermore, the entering substances may be changed in metabolism and, as important metabolite, still be given off to the milieu externe. This is called *secretion*, for instance of *sugars* in plants as nectarines, or milk in mammals. Finally, waste products may be *excreted*. In the sulphur bacteria, which dehydrogenate H_2S the sulphur may be formed intra- or extracellular (endo- and ectothiobacteria). Here it serves in both cases as substrate for further dehydrogenases. The above classification apparently breaks down (Frey-Wyssling;[13] Baas Becking, 1924b). It seems impossible to enumerate the substances given off by living cells. A few cases will be mentioned in the section on symbiosis. The milieu therefore receives;

a) concentrates by respiration

b) substances of high energy potential by secretion and

c) special substances by excretion.

When the organism dies it yields its materials to the cyclic changes further described in the following sections.

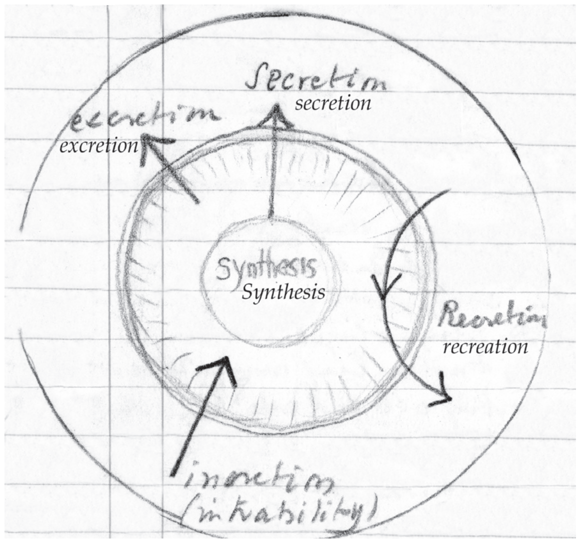

Figure 4.6 Schematic outline of secretion, excretion, recreation and incretion (intrability) of living cells.

4.2.5.b Temperature regulation

Heart regulation in poikilothermic animals is partly performed by increased respiration, partly by increased evaporation. As the heat of evaporation of water is high (580 cal/cm^3 at room temp.) great quantities of heat may be removed this way. A green leaf which absorbs ±7% of the incident radiation can be heated up in a short time to 70 °C if transpiration is prevented by coating the leaf surface with oil. The natural leaf surface behaves as a free water surface (law of linear dimensions of pores; Brown and Escombe, 1900), and in such a way, through evaporation, may maintain a temperature within the physiological range. On a sunny day at our latitude a leaf may receive 0.8 cal/cm^2/minute, absorbing 0.6 cal/cm^2/minute or in an 8 hour sunny day $8 \times 60 \times 0.6 = 288$ cal/cm^2. A free water surface will evaporate on such a day about 0.6 M or consuming *per* cm^2 0.6×580 cal = ±350 calories/cm^2. As the two results show the same order of magnitude it will be seen that the leaf does not need to become much warmer than the surroundings. It will, at the same time, supply the atmosphere with much water.

[In the margin Baas Becking added:] A large beach tree has a leaf surface of 1.00×10^6 cm^2 it would contribute 600,000 kg of water on one sunny day.

9 See Baas Becking and Galliher (1931).

10 Baas Becking probably referred to the Gibbs-Donnan effect about the behaviour of charged particles near a semi-permeable membrane that sometimes fail to distribute evenly across the two sides of the membrane.

11 Reference to Willem Hendrik Arisz (1888-1975), like Baas Becking a pupil of the Utrecht professor F.A.F.C. Went. In 1925 he became Professor in Plant Physiology in Groningen University. Baas Becking referred to Arisz (1943). Arisz wrote in the period 1937-1950 several studies about the active and passive absorption of substances in the *Proceedings of the KNAW*.

12 Baas Becking referred to Schuffelen and Loosjes (1942a and 1942b), and Lausberg (1935).

13 Reference probably to Frey-Wyssling (1938). Albert Frey-Wissling (1900-1988), Swiss botanist, who spent four years (1928-1932) in Medan as a plant physiologist at a rubber research station. In 1932 he returned to Zürich at the ETH in the Department of General botany. In the Leiden University Library, there are letters from 1931 between Frey-Wissling and Baas Becking (BPL 3562).

4.2.6 Summary and conclusions

There is a continuous give and take between the organism and its environment. This exchange lies at the base of geobiology. Apart from a chemical, and a physical instance of this exchange cited above, Sections 5, 6 and 7 deal with this matter more fully. But before dealing with these problems, it has to be stated specifically that organisms are in continuous interchange with their environment, a fact, apparently sometimes forgotten in laboratory and museum sciences. "Integer vitae" (when applied to material life) is a *contradictio in terminis*. Life is continuous interference of the milieu by life and of life by the milieu. Only a dried or stuffed specimen, sufficiently preserved, does not show such a relation. But then, it isn't alive anymore. Here also decision whether a process is due to milieu extern or due to milieu intern (leaves of *Canavalia*, Kleinhoonte and Brouwer, 1925).[14]

Text box 4.1 – Baas Becking notes made prior to writing the manuscript

Stones as large as man's fist have blown across the Sahara (Rohlf) and Gobi (Przhewalsky).[15] Fall of lichens was reported in Persia by de Candolle.[16]

Fishes, turtles Sandon (1927) found *Amoeba proteus* in soil collected from Greenland, England, Japan, Australia, St,Helena, Barbados, Mauritius, Africa, Argentine.[17]

Grabau (1913, p. 55).[18]

Deflation uniform upward in current will keep suspended quartz grains (Thoulet, 1908a and b).

Table 4.2 Velocity of wind for deflation of quartz grains of various sizes. From Thoulet (1908a and b).

Vm m/sec	ϕ quartz in mm
0.5	0.04
2.0	0.16
5.0	0.35
10.0	0.81
11.0	0.89
13.00	1.05

Distance, Gravel	a few feet
Conc sand 1-0.25 mm	several rods
Fine sand (0.25-0.125 mm)	less than a mile
Course dust (0.0625-0.03125 mm)	200 miles
Medium dust (0.03-0.015 mm)	1000 miles
Very fine dust	across the globe

April 1892 yellow China dust on deck ship West South of Nagasaki, at least 1000 miles distant.[19] Australia dust reaches New Zealand over 1500 miles. Sahara dust N. Germany. Dust rain Canary Islands, volume almost 4×10^6 m^3, 5 mm *per* century.

4.3 Distribution, Cosmopolitans, Physical Causes

4.3.1 Introduction

There is interplanetary distribution as well as terrestrial distribution to be considered. According to Lebedev, organisms should travel, once sufficiently outside the gravitational field, by radiation pressure.[20] Svante Arrhenius has actually suggested such a distribution. It remains to be seen whether any organism, even capsulated and dehydrated, could withstand the enormous intensities of ultraviolet radiation! Charles B. Lipman, in 1929, claimed to have isolated "very large" bacteria from a meteorite.[21] Dr. C.B. van Niel and the author had occasion to examine some of his cultures. They looked very much like *Bacillus megatherium* again! That these bacteria should come from the meteorite seems, at the least, improbable. Remaining for the moment, upon the earth, we shall consider the various methods of distribution of organisms over the surface of this planet in order to find the foundations of the cosmopolitan distribution of so many forms. It will appear that, below a certain critical size (see Fig. 4.7) the air is the universal medium of transport.[22] The other media, water and animate agents are, for microbes,

14 The reference is to Kleinhoonte (1929), Kleinhoonte (1932), Brouwer (1925), Brouwer (1926).
Gerrit Brouwer and Antonia Kleinhoonte (1887-1960) were students of Baas Becking's teacher F.A.F.C. Went. Kleinhoonte investigated the leaf movement of jack-bean and demonstrated diurnal motions and circadian rhythm, which corroborated the findings of botanist Jagadish Chandra Bose (1858-1937).
See also Barlow and Fisahn (2012).

15 Friedrich Gerhard Rohlfs (1831-1896), German geographer, was the first European to cross Africa from Tripoli across the Sahara Desert *via* Lake Chad along the Niger River to present day Lagos from 1865-1867; Nikolay Przhevalsky (1839-1888), Russian geographer. On his fourth and last trip, begun at Urga 1883, he crossed the Gobi into Russian Turkistan.

16 Baas Becking probably took this item from Free (1911). *The Movement of Soil by the Wind*:
"A fall of lichens with rain has been reported from Persia by De Candolle (1855) – *Géographie Botanique Raisonnée*, v. 2, p. 614-615".
The *Bulletins* of the Department of Agriculture must have been to his disposal when he was Professor of Economic Botany at Stanford University (1925-1928).

17 Sandon (1927) see also Wilkinson, Creevy and Valentine (2012).

18 Reference to Amadeus William Grabau (1870-1946), German-American palaeontologist and geologist. His *Principles of Stratigraphy* was first published in 1913.

19 John Milne (1892) reported about *A Dust Storm at Sea* in *Nature* (v. 46, no 1180, p. 128), June 9, 1892:
[...] On April 1, there was a fall of dust in the neighbourhood of Nawa in Okinawa-ken, and on the 2nd dust fell in Gifu-the district where the recent great earthquake took place. The P. and 0. S.S. Verona, which left Hong Kong on April 1, experienced the same phenomenon as the [Yokohama] Maru [on which Mr. Milne crossed from Shanghai to Nagasaki], the vessel being covered with a fine dust, which, when suspended in the atmosphere, gave rise to so much haze that land was not seen until reaching Nagasaki. On April 3, a yellow sun was seen in Yokohama, but I am not aware that any dust was observed. Roughly speaking, it therefore seems that on April 2, at a distance of from 200 to 400 miles from the coast of China, there was a cloud of dust which may have been over 1000 miles and possibly 2000 miles in length. Dr. B. Koto, who examined a specimen, tells me that the particles are chiefly felspar, but there is a little quartz and shreds of plants.
Tokio, April 23.
It is not clear whether Baas Becking obtained the information directly from *Nature*. The 1892 report in *Nature* is also quoted by Ken Wilkening (2011).

20 Reference to the 1901 publication of Pyotr Nikolaevich Lebedev (1866-1912). He was the first to measure the pressure of light on a solid body in 1899. The discovery became the first quantitative confirmation of Maxwell's theory of electromagnetism.

21 Baas Becking referred to Charles Bernard Lipman (1883-1944), Professor of Plant Physiology, University of California, Berkeley. Lipman (1932). Lipman seemed to be convinced in the presence of bacteria in meteorites and that these were semi-immortal organisms which had been there all the time.

22 Reference to Correns (1939), Figures 9 and 22.

decidedly of secondary importance. For higher organisms, however, there appear impediments to distribution, which cause the organisms to occur in certain, more or less defined areas. The area concept shall be dealt with briefly. See also [Dispersal of ashes after eruption of Mount Katmai, southern Alaska in 1912] Correns, p. 159.

4.3.2 Historical

On the accompanying Table 4.3 the relative size of various organisms is given, on a logarithmic scale, in relation to that of the electron and of the light year. (10^{-10} – 10^{+17} cm). Man, the measure of all things, has a central position in this explored universe. Organisms range from 10^{-6} – 10^{+4} cm. Air borne are organisms may be when sufficiently small. But the diagram given is misleading. According to this diagram, a minimum velocity of 100 m/sec, a veritable gale, should be required to carry a particle of 20µ radius. Now we know of many larger particles carried by air. They are probably lifted by an intense vertical air current, such as we find in storm clouds (cumuli) or in dust devils (the “pillar of cloud” of the Old Testament,[23] called ‘willie-willie’ in Australia).[24] Also the ascending air masses above volcanoes drag upwards huge masses of dust. Of course, an eruption may even contribute much more. (see *Royal Soc. Report* on Krakatoa, and the report of Verbeek and Ferzenaar).[25]

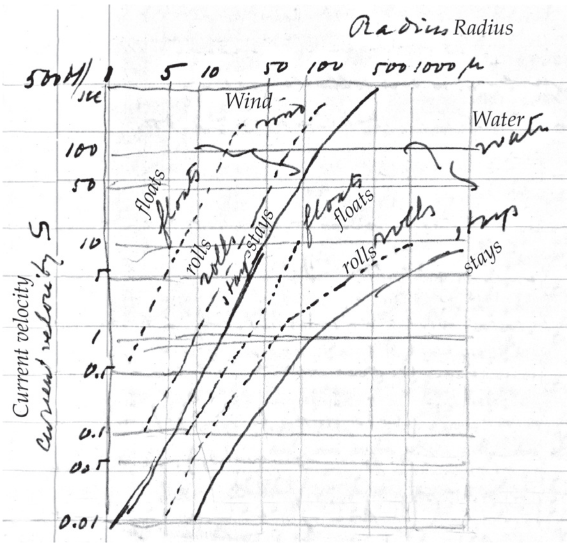

Figure 4.7 Transport limits for falling and rolling particles in air and water (S in m/sec) and grain sizes (in μ). From left to right: transport limit of falling particles in air (‘floats’); transport limit faling particles in air (‘rolls’); roll limit in air (‘stays’); transport limit falling particles in water (‘floats’); transport limit of falling particles in water (‘rolls’); roll limit in water (‘stays’). After Correns (1939, p. 149).

Table 4.3 The relative size of various organisms. From Correns (1939).

[Log10]							
17	→	Light year					
13	→	Distance earth-sun					
12							
11							
10							
9	→	Diameter earth					
8							
7							
6			Radio waves				
5							
4	→	Largest organism					
3							
2	→	Man (measure of all things)					
1							
0							
-1					Wind transports (rolls)		
-2			Microscopic	Infrared		Wind transports (floats)	Water transport
-3							
-4			Visible light				
-5	→	Smallest organism					
-6	→	Virus, phage	Ultraviolet				
-7	→	Molecules					
-8							
-9	→	Atoms					
-10							
	→	Electrons					

23 *Pillar of Cloud* one of the manifestations of God in the Torah, the five books of Moses which appear at the beginning of the Bible: *Exodus* 13:21-22, *Numbers* 14:14, *Deuteronomy* 1:33, Psalms 99:7, *Nehemiah* 9:12 and 9:19.

24 Reference to Australian aboriginal name ‘Willy Willy’, or ‘Dust Devil’, a strong, well formed, and relatively long lived whirlwind.

25 References to the Royal Society Report, The Eruption of Karakatoa, Symons (Ed.) (1888), Lipman (1932), Verbeek (1886), Captain H.J.G. Ferzenaar’s map of Krakatoa; Verbeek (1884).

It is not improbable that very large objects may be transported this way. Even fishes, turtles, frogs are known to have "fallen from Heaven." Granted the possibility of transport to considerable levels (say 10 km) the question remains what distance may be travelled before the particles settle down again. In practice, the particles should be not much longer as $\phi = 10^{-2}$ cm = 0.1 mm = 100μ.

4.3.3 Experiment of Louis Pasteur

It is said that the Chinese had a vague notion of the fact that infection diseases might be carried by air. During an epidemic the air was kept "moving" by noises made on luytes [lutes] and drums. A. v. Leeuwenhoeck (1682-1723) already fully recognised the importance of air transport and mentions it in his "Sendbrieven" at several places.[26] The father of protozoology, Ehrenberg, was convinced of the great importance of air transport of protozoa.[27] Darwin, at several places in his works, mentions the great influence such transport may have on the distribution of organisms.[28] It was left to Pasteur, in the course of his classic tilt on the subject of spontaneous generations, to prove, experimentally in a classic research the presence of organisms in the air (citations should be given from the original) (see Fig. 4.8). One of the early (1861) experiments shall be mentioned here in short. Outside air (w) was sucked through a tube filled with gum cotton (g) by means of a water pump. After several hours of suction, the gum cotton was dissolved in ether and the residue microscopised. Moulds, spores and yeasts were observed. Molisch coined the word "aeroplankton" for the organisms he observed sticking to slides moistened with glycerol.

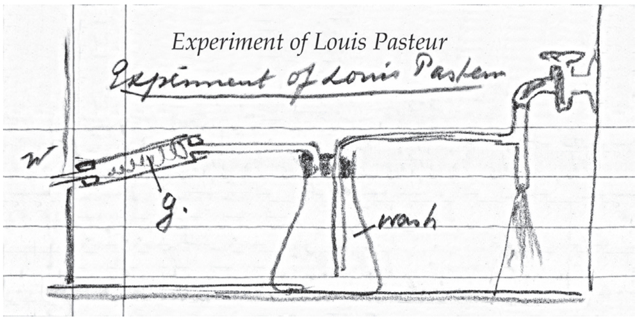

Figure 4.8 Experiment of Louis Pasteur (1861): W = outside air, g = gum cotton, the conical flask contains 'wash'.

4.3.3.a Wind transport of higher organisms

Amongst the higher organisms there are those fit for wind transport. Feekes, working on the dispersal of plants in the newly won Zuyderzee polders (Feekes, 1936) has performed much work on such forms as *Aster tripolini*.[29] A very beautiful adaptation one finds in the Cucurbitaceae, *Macrozamia macrocarpa*, in the fruit of the oak, of the maple, Compositae, *Clematis*, *Epilobium*, pine pollen, *etc*. Pine pollen has been demonstrated by the author in 1925, 200 km east of the nearest pine tree (Lone Pine) in the Californian desert. The spores of *Equisetum*, of ferns and mosses, the seeds of tobacco, of orchids are also fit for wind transport. Among flying animals, a great many function as a 'glider' and may cover enormous distances. Dr. N. Tinbergen told one about an aphid swarm arriving at Disco, Greenland, from Siberia.[30] The author observed 170 miles S.W. from the nearest New Guinea coast, honey birds and butterflies, carried by a strong N. Easterly wind.

4.3.4 Formulae[31]

Between the free fall:

$$S = \frac{1}{2}gt^2 \tag{4.1}$$

and the fall in a viscous medium, obeying Stoke's law velocity v,

$$v = \frac{2}{9}\, r^2\, \frac{g(d-d')}{\mu}$$

for a sphere, radius r, density of falling particle d, density of medium d′, viscosity μ, there exists a transition range. Also, for non-spherical objects a different fall velocity has to be expected. The subject also touches aerodynamics and its full treatment lies outside the scope of this essay. The resistance, exerted by an object against a current

$$R = kr^2v^n$$

in which r^2 represents the cross section of the object and v the velocity of the current, k is a constant and n is dependent on the stream velocity and fluctuates from medium speed to slower laminar movement from 2 to 1.

For flotation we obtain the limit

$$r^3\,(d-d').c = kv^nr^2$$

or the vertical current of air, carrying the organism should measure:

$$v = \sqrt[n]{c(d-d')r} \tag{4.2}$$

in which c is a constant. Restating Stoke's law in another form, we may write:

$$R = 6\pi r\mu v \tag{4.3}$$

If this resistance equals the moving force we arrive at the region where accelerated motion changes into constant motion. In that case

$$R = 6\pi r\mu v = \frac{4}{3}\pi r^3\,(d-d')g$$

Solving for v we obtain for the radius

$$r = \sqrt{\frac{9\mu v}{2(d-d')}}$$

For high velocities the law does not hold.

The equation of Sudry (1912), derived for objects falling in *water*

$$r = \frac{ad'v^2 + \sqrt{b\mu g(d-d')v}}{2g(d-d')} \tag{4.4}$$

26 See Baas Becking (1924a), Anthonie van Leeuwenhoek, immortal dilletant (1632-1723). Van Leeuwenhoeck wrote letters ('Sendbrieven') to the Royal Society in London with his microscopic observations.

27 Christian Gottfried Ehrenberg (1795-1876), German zoologist and geologist. In 1829 he accompanied Alexander von Humboldt through eastern Russia to the Chinese frontier. Ehrenberg examined samples of water, soil, sediment, blowing dust and rock and described thousands of new species, among them *Euglena* and *Paramecium aurelia* and *P. caudatum*.

28 Van Overeem (1936) in her PhD dissertation referred to Darwin's log book on board of the Beagle. Darwin collected an air sample which was examined by Ehrenberg.

29 Baas Becking (1936a) referred to the work of W. Feekes in the Wieringermeerpolder.

30 The later Nobel prize winner (1972) Nico Tinbergen and his wife spent a year at Greenland (July 1932-September 1933), shortly after he obtained his PhD in Leiden.

31 This page in the manuscript was taken by Baas Becking from Correns (1939, p. 136-139).

a and b are "form factors." For small velocities the equation becomes identical to Stoke's law, for high velocities we obtain Newton's resistance law

$$r = k(d-d')v^2$$

In *Geobiologie* (Baas Becking, 1934) equations are given derived by Humphreys (*Physics of the Air*).[32] They should be included in this consideration and supplemented with examples of falling velocity and falling time of various objects.

4.3.5 Apparatus of van Overeem

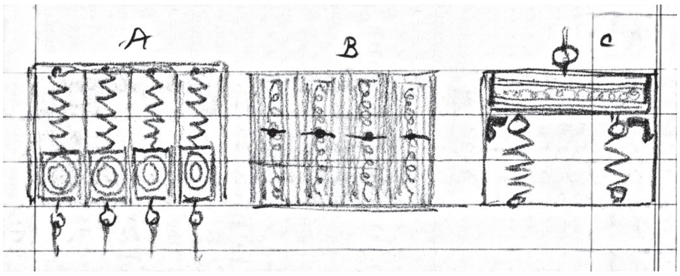

Figure 4.9 Van Overeem's (1936, 1937) sampling apparatus for aeroplankton, longitudinal section.

As already said Molisch (1917) used glycerol covered slides to study aeroplankton.[33] In relation to hay fever Dr. Benjamins, already in 1917, used this method.[34] It still is very instructive to expose such slides for a day on a high pole or on a roof to see what organisms appear. The literature on aeroplankton is surveyed by van Overeem. The great drawback of earlier work, including that of Miquel (1883), Meier and Lindberg (1935) and others, was that, apart from bacteria, only dead organisms were studied. In order to obviate this difficulty, while adhering to rigid sterile control, an apparatus was devised mounted under the wing of an airplane. It consisted of a series of hard glass tubes, open on both ends, and filled with glass wool. The tubes were placed in brass boxes and kept inside a larger, covering box (with overlapping lid), by means of strong springs. The entire apparatus was heat sterilised. From the various individual brass cables led to the cockpit where, by means of lamp controls, the position of the tubes could be ascertained.[35]

The apparatus was calibrated by my colleague J. Bonger in the wind tunnel of the Aerodynamic Institute at the Technical College Delft. It was shown that 10 minutes exposure at a speed of 140 km/hour, 1 cubic metre of air was filtered. Usually, exposure was made at 200-500-1,000 and 1,500 metres, one tube was always kept as control after the run (which was controlled by bacograph records) the apparatus was opened in a sterile chamber under rigorous sterile precautions and the glass wool divided over several culture solutions (here the solutions should be described). Bacteria, fungi, algae and mosses were obtained. Due to the small number of flying hours. However, results of only five m^3 are accountable.

4.3.6 Results of van Overeem

The air was sampled by a meteo-plane of the Netherlands Military Air Force (a Havilland, 1916).[36] All samples were taken over the airdrome of Soesterberg of algae *Stichococcus* and *Hormidium*, besides several diatoms, were obtained. Two species of Musci, [*Funaria hygrometrica* Sibth] and [*Ceratodon purpureus* Brid], were also found.[37] July 22, 1935 a sample of air taken at 100 metres yielded after 2 months culture a small object which looked like a young fern prothallus. It was taken from the culture solution with a capillary pipette and after two transfers "planted" in a piece of unglazed tile. Here the sporophyte developed and in the early spring of 1936 the plant was large enough to be classified as a *Thymian filix-femina* DC (we now have several large plants from the original).[38] Captain E. Visch, chief of the meteorological service of our Military Air Force made an analysis of the movement of the air masses previous to their arrival above Soesterberg (Fig. 4.10). It appeared that the last possible vertical motion of this air must have occurred over western Norway, and after that this air mass moved "clockwise" over Germany to arrive in Holland, and over the air during three days later. It therefore appears that our fern did travel at least three days.

The control of the experiment was such as to exclude any doubt. The air transport of viable sparks is proved. This also pertains, of course, to such seeds as *Orchidiaceae*, *Nicotiana etc.*, pioneers and a great many other living objects, insects or spores, cysts and eggs.

4.3.7 Other distribution factors

4.3.7.a Water

(Guppy, 1917). The coconut is the classic case of a water borne fruit which retains its viability after long immersion in seawater. A great many other plants have been tested in this respect. It appears that water borne seeds and parts of plants are in a large way responsible for the rehabilitation of sterilised volcanic islands (see however Bakker on Krakatoa).[39] Books

32 Humphreys (1929). Baas Becking referred to Humphreys in Chapter II of *Geobiologie* (1934; 2016 edition, p. 12). Humphreys calculated the time it took after the eruption for particles to return to the troposphere (11 km), assuming that the particles were spherical.

33 Reference to Molisch (1917). Baas Becking and van Overeem (1937) referred to the 1922 edition of Molisch's *Populäre Biologische Vorträge*.

34 Reference to Charles Emile Benjamins (1873-1940), medical doctor at Semarang (Java), Utrecht and professor at Groningen (1924-1939), specialist for Ear, Nose and Throat diseases. Benjamins published several articles on hay fever in *Nederlands Tijdschrift voor Geneeskunde*. From 1923 to 1926 he published four articles about hay fever in relation to the pollen of plants in Utrecht together with his colleague J. Idzerda and biologist Hendrik Uittien (1898-1944). Uittien was, like Baas Becking, a student at the Utrecht Botanical Laboratory and also did his PhD research under supervision of F.A.F.C. Went, Uittien (1929). He was taken prisoner because of illegal activities and executed in camp Vught August 10, 1944. See Lanjouw (1949).

35 The apparatus was described by van Overeem (1936). In this and the following section Baas Becking referred to Marie Antoinette van Overeem's PhD thesis (1937), *On Green Organisms Occurring in the Lower Troposphere*. Baas Becking was van Overeem's supervisor in Leiden. According to van Overeem the calibration was done by Mr. G. Broersma.

36 Baas Becking referred to The Havilland Airco DH.4, British two seat biplane day bomber of the First World War. M.A. van Overeem however, in her 1937 thesis, referred to a Fokker C VI. The pilot was her future husband Captain Egbertus Visch (1896-1992). From 1952 until 1963 Visch was a member of the Dutch parliament on behalf of the Roman Catholic Party (KVP). In October 1946 Visch together with vice-Admiral L.A.C.M. Doorman presented the provisional plans for the exploration of New Guinea to the Coordination Commission for Scientific Affairs. Baas Becking was Chairman of this Commission and he considered the plans as immature and premature.
Source: NA 2.10.14 inv. 5633, advies inzake plannen Nederlands Nieuw Guinea Exploratie Comité, Batavia October 2, 1946; Letter L.G.M. Baas Becking's Lands Plantentuin Buitenzorg, 16 juli 1947 to Prof Dr. J. Clay, Nat. Lab. Gem. Univ. Amsterdam. Archive Museum Boerhaave Leiden.

37 According to van Overeem (1937, p. 422 and 427).

38 Lady fern *Athyrium filix-femina*.

39 Cornelis Andries Backer (1874-1963), Dutch botanist. Backer joined on two expeditions to the Krakatao, in 1906 and 1908. In 1929 Backer published his controversial book, *The Problem of Krakatao, as seen by a Botanist*, in which he maintained that not all plant life had been destroyed by the gigantic eruption of the volcano, but that rootstocks and diaspores might have been buried to sprout again. See Thornton (1996, Chapter 6, *The Krakatau Problem*, p. 78-96).

on plant "biology" mention endless series of adaptations to water dispersal. (This section should be extended literature not available).

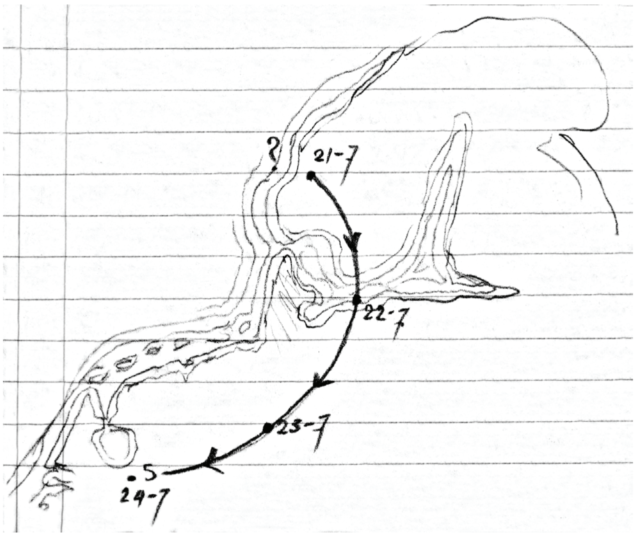

Figure 4.10 Windtracks from Bergen (Norway) to Soesterberg (Netherlands), 25 August - 28 August 1936.

4.3.7.b Man

(H. Molisch). The common plantain (*Plantago media* L) has been aptly called 'the white man's footprint.' Not only this plant but also *Senecio*, *Avena fatua*, *Bellis perennis etc.*, follow man everywhere he goes. The tracks of the old Amber roads in Europe are said to be marked by a plant *Illicetrum verna*.[40] Many other instances could be cited!

4.3.7.c Other animals

(Myrmecophilous) plants are not only the classical cases mentioned by Schimper,[41] such as *Lecropia*, *Acacia farinosa*, *Hydrophytum* and *Myrmecodia*, but plants, the seeds of which possess glandular tissue which, through its sugar content, attracts the ants and makes man distribute the seeds (*Myrmecodias*). Buds are transmitted by animals with woolly pelts. Kerner von Marilaun gives good figures.[42] Many seeds are in fruits used as food (apple, cherry).

4.3.7.d Obstacles, area

Although so many instances of dispersal are given, still it seems that the majority of higher organisms stick to a rather narrowly prescribed area. It is the hypothesis of Willis that this area expands very slowly and that the larger its extent, the older the species (or genus).[43] This "age and area" hypothesis is much debated, but has been, together with the theory of Wegener, a most stimulating influence on biogeography. It is often astonishing how two races of butterflies, for instance, live only a few miles apart on a mountain slope (Toxopeus, New Guinea) without, apparently, any intermingling.[44] Only profound investigation will show the reason of these and many other facts connected with distribution, which we cannot mention here.

4.3.8 Inventarisation of area concepts

The area concept has, in the hands of contemporaneous plant geographers like Danser, Lam and van Steenis yielded much valuable information and has led to important generalisations.[45] Nevertheless, we cannot push the idea of area to the limit. Professor Diels, the Berlin plant geographer, has published a well known atlas of plant areas.[46] As far as higher plants are concerned, these maps are of great use, but Diels, not satisfied with this, has descended downward into the algae, and published area maps of Desmids! It seems to the author of this book that those maps are really not a map of the distribution of algae, but of the distribution of the algologists, as Desmids are lacking nowhere, are easily transported and are so conspicuously similar in the United States and in the United Kingdom that it requires little commentary to see that they are probably of cosmopolitan distribution. It is remarkable that Charles Darwin when talking about distribution (*Origin of Species*) gives complete precedence to cosmopolitans and *then* goes to inquire *why* the non-cosmopolitans are not of wider distribution! Think of migratory birds, a regular ferry service between the tropics and the moderate climes; what number of algae are ferried over from Central Africa to Holland by swallows and storks? The map of Desmids most probably being a map of algologists we may turn to other area maps which are apparently maps of the distribution of sand dunes, or of peat bogs. There are a great number of higher plants and animals bound to a biocoenosis, but *always* present in that biocoenosis. The omnipresence of life is our first thesis. The sifting action of the

40 Baas Becking referred to the Coral necklace, *Illecebrum verticillatum* L., 1753, a species distributed along roads, according to him also along the Amber Road, the ancient trade route for the transfer of amber from coastal areas of Sicily to Greece and Spain. From the 16 th century amber was moved from Northen Europe to the Mediterranean area. The oldest roads avoided the alpine areas. In *Kingdom of this World* (1942-1943) Baas Becking referred "to the Baltic amber-trail described by Victor Hehn" (p. 85).
So, there are, in the animal kingdom, apparently several types of roads. The one is the extension of the nest, it outskirts the realm, it connects its vital points. This realm may be, virtually the world (as in the case of certain whales and fishes and birds), or it may be confined to a few square yards, as the small *Larius*, a yellow ant that lived under the flagstones of my verandah in Java. The old salt tracks of humanity and the Baltic amber trail, described by Victor Hehn, are typical "nest roads". Victor Hehn (1813-1890) German-Baltic arthistorian. Baas Becking referred to his *Das Salz. Eine kulturhistorische Studie* (1873).

41 Andreas Franz Wilhelm Schimper (1856-1901), German botanist and phytogeographer, best known for *Pflanzengeographie auf Physiologischer Grundlage* (1898). Myrmecophily term applied to positive interspecies associations between ants and a variety of organisms such as plants, other arthropods and fungi.

42 Anton Kerner Ritter von Marilaun (1831-1898), Austrian botanist. Baas Becking probably referred to *The Natural History of Plants, their Forms, Growth, Reproduction, and Distribution* (1895-1896), or an earlier German edition of the original *Pflanzenleben*.

43 John Christopher Willis (1868-1958), english botanist, known for his 'Age and Area'- hypothesis, defined by him as:
> The area occupied at any given time, in any given country, by any group of allied species at least ten in number, depends chiefly, so long as conditions remain reasonably constant, upon the ages of the species of that group in that country, but may be enormously modified by the presence of barriers such as seas, rivers, mountains, changes of climates from one region to the next, or other ecological boundaries, and the like, also by the action of man, and by other causes.

44 Lambertus Johannes Toxopeus (1894-1951), Dutch entomologist, member of the third Archbold expedition to New Guinea (1938-1939), expert on butterflies (family *Lycaenidae*).

45 The reference is to Benedictus Hubertus Danser (1891-1943), student of Hugo de Vries and later of Theo Stomps. After several years in the Herbarium in Buitenzorg, he returned to Groningen where he became professor of Plant Morphology in 1932.
Herman Johannes Lam (1892-1977), director Rijksherbarium Leiden. See Jacobs (1984).
C.G.G.J van Steenis (1901-1986), botanist, founder and editor Flora Melesiana, colleague of Baas Becking in Buitenzorg and after WWII professor in Leiden. See van Steenis-Kruseman (1990).

46 Friedrich Ludwig Emil Diels (1874-1945), German botanist, Professor of Botany and director Berlin-Dahlem Botanic Garden. Baas Becking referred to: Diels, Samuelsson, Hannig and H Winkler (1926-1931).

milieu the second. The work of van Overeem has established experimentally the most of distribution. About the selective activity of the milieu see Section 5 of this book.

4.3.9 Integration of "everything is everywhere"

The milieu is a veritable resonator. The modern methods of microbiology are a witness to the fact. There is more, however, if one witnesses the digging of a canal in the dunes, a ditch without communication with other open water, one will be amazed about the wealth of organisms, including fishes, which appear in the body of water within a year. If the milieu is aberrant, the results are even more striking. In 1929 near the salt mines in the eastern part of the Netherlands, Boekelo, a salt bath was made. The brine, pumped up from great depth, was first decalcified by means of alkali, so that a solution, poor in lime and magnesia, pH 9.4 resulted. This was inoculated with seawater, but only one diatom, *Rhizosolenia* developed. The solution had nothing in common with seawater but the 3 % NaCl. After a few months, however, typical salt loving organisms developed, found by the author in Soda Lake, Nevada, 4 years previously. Now Soda Lake has a composition not unlike the artificial brine of the salt bath. A rotifer, *Brachionus Mülleri*, was apparent and the bluegreen alga *Aphanothece*, further *Dunaliella salina* and several other flagellates. The next year even the salt fly, *Ephydra*, appeared![47] The pupae of which formed veritable floating cakes! The nearest locality where to expect this fly is Mulhouse, ±400 miles to the south east! One could increase the number of examples as well, experimental brine tanks at Leiden have shown similar development (*Asteromonas*, *Brachiomonas*). The universal distribution of a great number of organisms seems therefore, well established.

4.4 Latent and Active Life

4.4.1 Introduction

[Baas Becking inserted in the margin a small sketch (Fig. 4.11).]

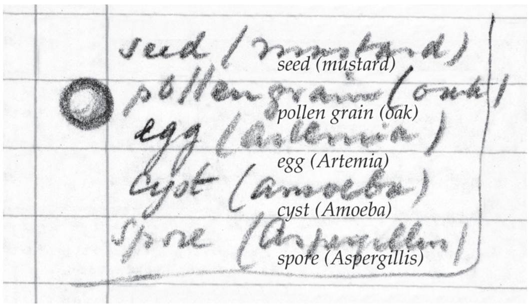

Figure 4.11 Small sketch in the margin of seed/mustard, pollen grain (oak), egg (*Artemia*), cyst (*Amoeba*), spore (*Aspergillis*).

A hard spherical object, not readily permeated by water such as often a seed, a pollen grain, an egg, a cyst or a spore. Within its secure shell life is latent. Maybe in a dehydrated stage, water sometimes being replaced by oil. Vitality and water content seem to go parallel in the range of the 'almost dry.' In such structures, metabolism is at a very low ebb and this indeed is the reason why these states can persist over such long periods. There is hardly any CO_2 produced. In life cycles of insects, we find the pupa and while metabolism may be at a very high level here, still the chrysalis is a structure which may permit in semi-latent condition for a long period of time (Shelford, 1929). We know very little about the well protected buds in higher plants, but it is safe to assume that here also we meet with a structure fit for latent life.

4.4.2 Longevity of seeds and spores: historical

"Dormancy" is the term used by many authors to describe this latent stage. Here we meet with periodic phenomena, chiefly in the animal cycle, often, in a rather vague way called *hibernation* and *estivation*. In hibernation the vegetative stage of the animal suddenly shows a drop in metabolism, from eurythermic the animal becomes cold blooded – poikilothermic. Accumulation of waste urea in the blood enhances the comatose condition which we meet in *Platypus*, Insectivora, rodents and bats. The lipase activity increases, the animal uses its reserve fat. On reawakening the temperature may increase almost explosively. Roubard (cited by Shelford) has developed a theory where, in anthomyid *Diptera*, dormancy is brought about by a period of intense metabolic activity in which an abundancy of urates are formed. These urates are voided into the malpighian tubules during dormancy. The theory could not be substantiated by experiment of other authors. A high CO_2 pressure in the atmosphere may cause animals to enter into a dormant period also.

4.4.3 Longevity of seeds and spores: recent

In 1936 the author obtained from his colleague Prof. J.G. Wood at Adelaide sporocarps of the water fern *Marsilia drummondi* (common fern in inland Australia called Nardoo) collected during the Horne expedition to central Australia, 1881.[48] The sporocarps were sent to the Botanical Museum at Leyden but an enterprising gardener of the Leyden Botanical Garden, Mr. J. Lagendijk, planted the sporocarps and raised beautiful ferns from them. They had been dormant for 55 years. Joly (1840) collected eggs of the phyllopod crustacean *Artemia* in Troarn, 1830. V. Siebold raised nauplii from those eggs in 1875 (?).[49] *Artemia* eggs collected by the author in 1929 had lost their generating power entirely in 1939.[50] It may be that these eggs, however, were not efficiently dried. Dr. D. Kuenen still raised nauplii from them in 1937.[51] At the laboratory of microbiology at Delft, director Prof. A. Kluyver, there is a sample of soil, obtained from L. Pasteur's experiments on anthrax, 1868 (?). H.G. Derx cultured the anthrax bacterium from this soil ±1920.[52]

47 The alkali fly *Ephydra hians*. Baas Becking referred to the Boekelo research published in Nicolai and Baas Becking (1935). The 10 page typescript of the preliminary report of August 1934 on the salt bath ('zoutbad', a swimming pool) at Boekelo is in the Australian Baas Becking Archive AAS 043 nr.161-27. In the 1953 manuscript of *Geobiology* (Baas Becking, 1953a, p. 136-137) there is also a reference to this study.

48 Joseph Garnett Wood (1900-1959), Australian Professor of Botany University Adelaide (1935-1959). In 1937 Baas Becking and Wood published *Notes on Convergence and Identity in Relation to Environment*, in *Blumea*.

49 Reference to Karl Theodor Ernst von Siebold (1804-1885), German physiologist and zoologist. He was responsible for the introduction of the taxa Arthropoda and Rhizopodsa and for defininbg the taxon Protozoa.

50 The eggs of *Artemia* came from a two acre saline near Marina, California. The yield over the 1928-29 season was "conservatively estimated" 100 pounds. See Boone and Baas Becking (1931), *Salt Effects on Eggs and Nauplii of Artemia salina* L.

51 Warren, Kuenen and Baas Becking (1938), Kuenen and Baas Becking (1938), Kuenen (1939).

52 Baas Becking referred to the experiments of Louis Pasteur in 1877 on the anthrax epidemic, which killed sheep and was attacking humans as well. In 1881, in a large scale public experiment, he successfully immunised sheep.

Seeds may remain dormant for over 40 years, as reforestation has shown in areas which were also previously wooded. The forest herbs and grasses reappeared as soon as the young plantation gave sufficient hummus and shade. Certain *Dermestidae* larvae (museum beetles) (= *Anthrenus museorum*) may persist for more than four years in almost suspended animation. Mosses are raised from spores out of old herbaria by Becquerel.[53] The greatest span being ±80 years. The above cases should be extended to longevity of agricultural seeds (like Becquerel). The stories of the survival of wheat grains in Sarcophagi are obvious frauds. The literature is also compiled by Molisch (1917).

4.4.4 Hydration and activity[54]

The work of Beyer has shown the ability of the clothes' moth to use the water derived not from the combustion of food, but of tissue. He fed moth on wool dried at 105 °C in a dry atmosphere and while the animals lost weight rapidly, their water contents remained the same.[55] In mammals this water content cannot be lowered more than 10 % without lethal consequences. Desiccation is chiefly a matter of excessive evaporation, and when this may be checked animals may survive in very dry habitats. The amphibians of the desert (horned toad, Gila monster *etc*.),[56] are provided with a very heavy skin (still amphibians have to respire partly through the skin).

It is known that activity in both animals and plants, sets in when previously desiccated tissue (seed, cyst) attains water again. The reaction is again of an "explosive" nature. Although investigations upon this point are scanty, it is known that enzyme activity is highly influenced by electrolyte concentration of the milieu, and it may well be that in desiccated cells some of the water is still in the "free" condition (see Section 3.5.21) but that the solute concentration in this water is too high to allow for enzyme action and, therefore, for metabolism. The book of Shelford (1929) gives a number of disconnected and anecdotical statements that need much amplification. It seems that experimentation upon this most interesting topic is still scanty.

4.4.5 Concentration

Another factor, which influences activity of life, is the concentration of the foodstuff. There should be plenty. "Plenty" presupposes a concentration which we find in relation to bacteria, in the gut of a host animal, where a high concentration of foodstuff is present. The bacteria may develop quickly here and produce their own metabolic ergones, which are as insects are to plant life when excreted in the soil.

4.4.6 Abnormal temperatures

(See *Geobiologie,* Baas Becking, 1934). Latent stages are often highly resistant t[illegible] (1919) kept the sp[illegible] oil bath at 150 °C. N[illegible] beetles persist at temperatures of liquid hydrogen (-250 °C (?), Rahm, 1924).[57] Beijerinck has tried survival of various organisms in hydrogen and helium. Bluegreen algae, which should be considered as primitive, did not survive, as they lost their accessory pigments, phycocyanine and phycoerythine. Certain fishes (*Cottoidae*) may be frozen solid for a season.[58] Frogs may withstand freezing if only the heart keeps beating. Further facts about frost resistance, in relation to bound and free water are given in Section 3.5.21. Hot springs are treated in Section 5.2.4. It seems that there are many forms of protoplasm that do not coagulate under 70-80 °C (bacteria, bluegreen algae, flagellates, amoebae), This section should be materially extended. D_2O does not increase the thermo-tolerance of *Dunaliella* (Baas Becking, 1935).

57 Rahm (1924) reported that dehydrated tardigrades survived exposures to -253 °C in liquid air up to 20 months.

4.4.7 Summary and conclusions

Susceptibility to high extreme temperatures, as well as latency (dormancy) seem closely related to the water factor. This factor, which we meet everywhere on our path, dictates enzyme action, and enzyme action dictates metabolism. The less the water content of the tissues, the less the approach to boiling point and to freezing point of water will influence the metabolism. If salt loving creatures show a higher dehydration their obvious relation to (or identity with) thermophilic organisms may be accounted for.

4.5 Metabolism

4.5.1 Introduction

Metabolism is the chemical milieu relation with particular references to changes in the internal milieu. Here the living cell either forms compounds with a higher energy contents out of others, of lower potential, like in photosynthesis, or it lowers the energy potential of the substance involved (see Section 4.6). In the first instance it lays up potential energy,

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53 Paul Becquerel (1879-1955) French physiologist and specialist in plants. Baas Becking referred to Becquerel (1925 and 1935).
In the 1953 manuscript of *Geobiology*, Baas Becking (1953a) referred (p. 132-133) to Becquerel as follows:
Paul Becquerel […] has shown that hard coated leguminous seeds possess a considerable longevity.

Cassia multijuga Reich	158 years
Cassia biocapsularis L	115
Leucaena leucocephala L	99
Dioclon pauciflora Reich	93
Astragalus massilliensis Lam	86
Cytisus biflorus L'Hér.	84
Mimosa glomerate Forssk.	81

Of the species examined by Becquerel with a survival time of more than 50 years, only two species of seeds were non-leguminous, *Lavatera pseudo-olbia* Desf. (Malvaceae) and *Stachys nepetifolia* Duch (Labiatae).

54 Baas Becking uses the Dutch word 'hydratatie' instead of the english 'hydration'.

55 'Beyer' not identified. In the 1953 manuscript of *Geobiology* (p. 244-245) Baas Becking referred in the Section *Metabolic Water* to Beyer:
Organisms living under conditions of drought, whether exposed to the atmosphere, or in non-aqueous solutions, have to subsist on metabolic water. The best known cases are the flour moth and the clothes moth.
See also Section 3.5.18.

56 Horned lizards (*Phrynosoma*), also known as horny toads of horntoads, a genus of north American lizards.
Gila monster (*Heloderma suspectum*), a species of venomous lizard native to southwestern USA and northwestern Mexico.

57 Rahm (1924) reported that dehydrated tardigrades survived exposures to -253 °C in liquid air up to 20 months.

58 For a recent study about low temperature tolerance of Cottidae see Yamazaki *et al.* (2019). Their results suggest that within the superfamily *Cottoidae* the family *Cottidae* have adapted to each location by expressing optimal antifreeze activity level. The species in *Cottidae* could occupy the cold regions by acquiring various functional genes such as AFPs [= Anti-Freeze Proteins].

in the other case it liberates kinetic energy. Finally, all this kinetic energy will be liberated as heat, as careful energy balances (Algera, 1932; Tamyia, 1932), have shown. Synthesis of the specific protoplasm is one of the most intricate of metabolic processes, a form of metabolism as yet very imperfectly understood (L.W. Henderson, 1913; Chibnall, 1939; Bergmann).[59] The basis of all plasmic systems, as well of all energy related metabolism is the molecule of βglucose, synthesised by the green plant and convertible in the vast number of metabolites. The details of its mode of origin from the CO_2 molecule are still obscure.

4.5.2 Catabolism and anabolism

Catabolic processes are concomitant with a decrease in energy potential of the substances formed (Fig. 4.12). If we take glucose again as reference substance, 674,000 calories may be liberated in complete oxidation to CO_2. Anabolic would be all processes, in which the energy potential is varied. If CO_2 is taken as a reference substance (potential of 674,000 calories of useful work (free energy) are required to synthesise 1 mole of glucose out of 6 moles CO_2). Plasmic synthesis may exceed this value materially. Still, these protein molecules with very high energy value are few as compared to the number of contributing metabolites. In this way the process of plasmic synthesis becomes understandable energetically.

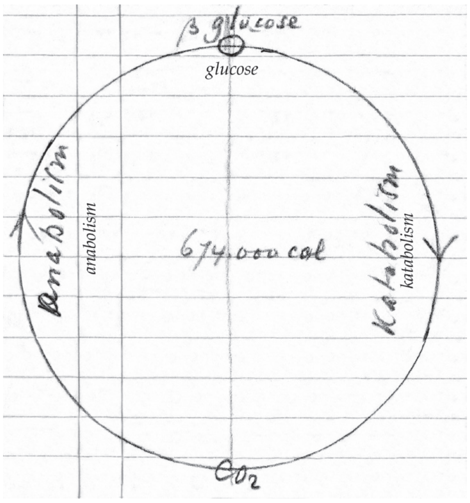


Figure 4.12 Energy potential for complete oxidation of glucose (catabolism) and synthesis of glucose from CO_2 (anabolism).

4.5.3 The role of hydrogen, oxygen, water and CO_2

See also Section 5.11.12.

Nearly all metabolic processes of which only C, H and O are concerned (glucose metabolism) may be reduced to form pairs of fundamental reactions (Fig. 4.13), what according to some should be reduced to three pairs, to wit:

1. Hydrogenation and de-hydrogenation,
2. Hydration and de-hydration,
3. Carboxylation and de-carboxylation,
4. Oxidation and de-oxidation.

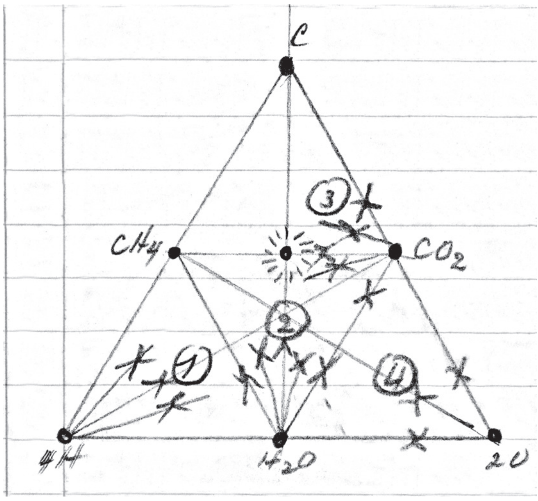


Figure 4.13 Equilateral triangular plot with compounds C – 4H – 2O representing the glucose metabolism. 1. Hydrogenation and de-hydrogenation. 2. Hydration and de-hydration. 3. Carboxylation and de-carboxylation. 4. Oxidation and de-oxidation.

The last pair may be much less fundamental. The equilateral triangle depicted shows C, H, and O compounds and their atomic compositions, as will be further used in this essay. The arrows give the direction of the reactions. The "sun" in the centre represents glucose.

4.5.4 Inorgreductants

Plant and bacterial cells are able to reduce CO_2, in some cases completely to methane, mostly "halfway" (see diagrams) to carbohydrate. They are able to reduce nitrate, sometimes to nitrite, sometimes to nitrogen and even to ammonia. They reduce the positive pentavalent nitrogen to negative trivalent nitrogen. They are also able to reduce the hexavalent positive sulphur from sulphate to the bivalent negative sulphur in sulphides and in amino acids. There are indications that the pentavalent positive phosphor atom may be reduced to the trivalent negative atom by certain bacteria (see Section 3.8.6), but confirmatory evidence is still lacking.[60]

The animal cell is unable to perform any of these reductions, and therefore it is apt to stress this point that *plant cells are able to reduce the inorganic, oxidised, milieu, that plant cells are inorgoxidants*. This point is of the utmost geobiological importance. For the reduction of nitrates Warburg and Negelein have shown dependence upon photosynthesis.[61] This dependence does not exist in bacteria, neither the other

59 Reference to Henderson (1913, p.129, edition 1970):
Now of all known physical structures there is none which rivals protoplasm in its fine complexity, and adsorption is therefore a prominent agent in deciding its physico-chemical constitution.
Reference to Max Bergmann (1886-1944), Jewish-German biochemist who left Germany in 1933 and was active at Rockefeller University New York. Baas Becking probably referred to: Bergmann (1934), *Synthesis and Degradation of Proteins in the Laboratory and in Metabolism.* See also Deichmann (2001).

60 In the 1953 version of *Geobiology* (p. 673) Baas Becking remarked:
The element is only acceptable at the completely oxidised level. The organo-phosphorus compounds occurring in nature (nucleic acids, lecithinoids *etc.*) all show this level or the phosphorus. There is some evidence that a reduction of phosphate, analogous to that of sulphate or of nitrate, may occur in anaerobic, acid environment, yielding the, spontaneously inflammable, phosphine, PH_3. The 'will of the wisp' in the moors has been ascribed to the combustion or PH_3, but no conclusive experiments have been performed, far as I am aware. Organisms may remove phosphorus, like silica almost quantitatively from the aqueous milieu.

61 Reference to Otto Warburg (1883-1970), won the Nobel Prize in Medicine and Physiology in 1931, and his longstanding collaborator Erwin Negelein (1897-1979) who studied the process of photosynthesis, published in 1922 and 1923. Baas Becking referred to Warburg and Negelein (1922); Warburg and Negelein (1923). See also Nickelsen (2007); Section 4.5.4.

inorgreductions. The intrinsic meaning of all this is that plants are able to reduce hydrogen-oxid, water to hydrogen and oxygen.

4.6 Photosynthonts

The photosynthont makes use of sunlight to reduce the carbon dioxide. Nearly all of these organisms possess special organelles, plastids, in which several pigments are present. Only in photosynthetic bacteria and in the bluegreen algae such plastids cannot be demonstrated. The pigment chiefly concerned in photosynthesis is chlorophyll. The enchlorophyll absorbs light maximally at an in the red region of the spectrum (maximum at 6810 Å). The purple bacteria possess an absorption maximum at the near infrared (8900 Å). The mechanism of the process is but imperfectly understood. Most probably, *per* molecule of CO_2, two molecules of water are decomposed on or near the chlorophyll, using four light quanta to perform this feat. The hydrogen is transferred to the CO_2, two atoms being incorporated in the molecule, and two others used to form one molecule of water, the over-all reaction being:

$$CO_2 + 2\,H_2O = HCOH + H_2O + O_2$$

HCOH stands for 1/6 of the molecule of glucose, energy requirement of synthesis being 1/6 × 674,000 cal, almost equal twice the heat formation of water, as the hydrogenation of CO_2 takes place with but little energy exchange. The photosynthesis of the purple sulphur bacteria takes place according to:

$$CO_2 + 2\,H_2S = HCOH + H_2O + 2S \text{ (Van Niel, 1932),}$$

or, in general, the equation should run:

$$CO_2 + H_2X = HCOH + H_2O + 2X.$$

In certain cases, X may be zero and we get a direct CO_2 accumulation by means of hydrogen (purple bacteria, algae, sulphate reducers). Chlorophyll has been found in petroleum (Treibs, 1936).[62] Native chlorophyll was found in grass from a stable in a roman castellum from Drusus' days (460 A.D) under anaerobic conditions (Neumann, 1940). It is probable that the CO_2 is highly hydrated (orthocarbonic acid) before being decomposed (Baas Becking and Hanson, 1937). Products intermediary between CO_2 and β glucose have not been established satisfactorily. It is probable that *l*-ascorbic acid (or other diënolic compounds) plays an important role in the mechanism of the process.

The efficiency of the photosynthesis may be very high, even up to 70 %. Unfortunately, only a very small fraction of the incident sunlight is utilised. The process of photosynthesis is that which makes the earth inhabitable for their organisms. Glucose is the centre of the biochemistry, the substance from which every biological compound may be derived (see Fig. 4.14). It should be emphasised strongly that, in the modern theory of photosynthesis, the oxygen evolved originates from the decomposition of water and not from the decomposition of the carbon dioxide.

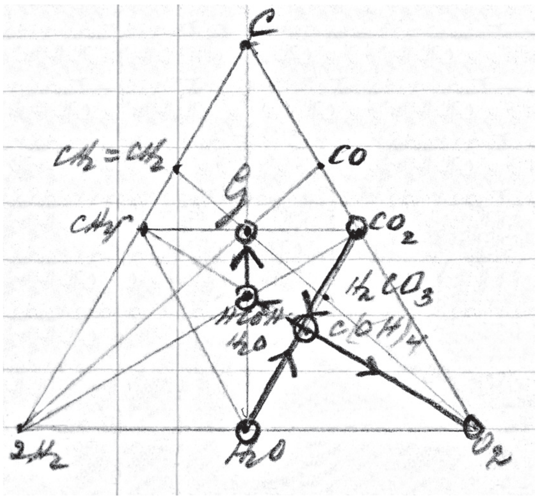


Figure 4.14 Equilateral triangular plot with compounds C – 4H – 2O representing the synthesis of glucose (G) from CO_2 and $2H_2O$ by photosynthesis.

As to the light, a minimum of 4 h γ seems to be needed to reduce one molecule of CO_2. For the purple sulphur bacteria, it may be concluded that the reaction:

$$CO_2 + 2H_2O \rightarrow HCOH + H_2O + O_2$$

also takes place, but that this reaction is followed by:

$$2\,H_2S + O_2 \rightarrow 2\,H_2O + 2S, \text{ yielding } CO_2 + 2\,H_2S \rightarrow HCOH + H_2O + 2S.$$

Makamura claims to have obtained experimental evidence for this reaction.[63] If this were true, the photolysis of water would be the primary reaction again. If hydrogen is given as such it reacts, in the case of the sulphur bacteria (Roelofsen, 1934). Also, in green algae recent work has shown the efficient reaction of hydrogen (Gaffron).[64] The substrate of photosynthesis is the plastid, containing always chlorophyll (see Hubert, 1935).[65] It is probable that the fluorescent light emitted by the irradiated chlorophyll protein complex activates the H atoms in the maximally hydrated CO_2 molecules. The implication of photosynthesis on the milieu will be dealt with in Sections 5 and 6. In the above diagram H_2O and O_2 are reacting, forming the orthocarbonic acid $C(OH)_4$, which under the influence of light and by absorption of $4h\nu$ [energy of 4 photons in joules; h = Planck constant ν = the photon's frequency] disintegrates into O_2 and hydrated aldehyde, which is soon conversed to β glucose (G in the diagram). Energy requirement *per* mol β glucose 674,000 cal, requiring 12 mols of H_2O to be decomposed 4 *per* mol H_2O 56,000 cal, which checks may well with the heat of decomposition of water!

4.7 Chemosyntonts

S. Winogradsky, in 1887, discerned bacteria that were able to persist on purely mineral media if only a chemical energy source were made available. Winogradsky (1922) named

62 Reference to Alfred E. Treibs (1899-1983), German organic chemist. In the 1930s Treibs discovered metalloporphyrins in petroleum. These porphyrins resemble chlorophyll. This discovery helped confirm the biological origin of petroleum, which was previously controversial.

63 Reference not identified.

64 Baas Becking referred to Gaffron (1939), *Reduction of CO_2 with H_2 in Green Plants*; Gaffron (1940), *Carbon Dioxide Reduction with Molecular Hydrogen in Green Algae*. Gaffron discovered the hydrogen metabolism in unicellular green algae.
Hans Gaffron (1902-1979), emigrated in 1937 to the USA and became a Visiting Research Associate at the Hopkins Marine Station in Pacific Grove. There he worked with Cornelius B. van Niel. He had several academic positions. He was an expert on photosynthesis and biochemistry of plants. Baas Becking referred to his work in Germany and USA on photosynthetic green alga hydrogen research. See Melis and Happe (2004), Deichmann (1996, p. 223).

65 Reference to B. Hubert, a PhD student of Baas Becking in Leiden. In 1935 he defended his thesis, *The Physical State of Chlorophyll in the Living Plastid*. The dissertation was not discussed by Baas Becking in this manuscript of *Geobiology*.

these organisms "inorgoxidants",[66] because they derived the energy, necessary for the assimilation of the carbon dioxide from the oxidation of inorganic compounds. In nature, there occur a great many of those oxidations, and every single of them is not left unutilised by a specific bacterium. The aerobic chemosynthesicates, as we name them, are therefore almost predictable. We find those that utilise the energy liberated by the oxidation of:

1. Ferrous iron: the iron bacteria (*Leptothrix ochracea. Gallionella, Toxothrix, Siderocapsa*):

$$Fe^{2+} \rightarrow Fe^{3+}$$

2. Sulphur and hydrogen sulphide, the sulphur bacteria (*Thiotrix, Beggiatoa, Thiobacterium, Thioploca, etc.*):

$$H_2S \rightarrow S;\ S \rightarrow SO_4^{2-}$$

3. Hydrogen, the hydrogen bacteria (*Hydrogenomonas, B. statzesi, B. pantotrophus*)

$$H_2 \rightarrow H_2O$$

4. Carbon monoxide, the carbon monoxide bacteria (*B. oligocarbophilum*)

$$CO \rightarrow CO_2$$

while most important for agriculture is the oxidation of:

5. Ammonia by the nitrobacteria (*Nitrobacter, Nitrosomonas*)

$$NH_4^+ \rightarrow NO_2^-$$

6. Nitrite by the nitrobacteria (*Nitrobacter*)

$$NO_2^- \rightarrow NO_3^-$$

There are several other groups, chiefly concerned with sulphur compounds, we shall not endeavour to enumerate them all (see monograph by Bunker, 1936).[67] We shall deal with the individual groups more in detail, suffice it here to say that, in contrast to photosynthesis the efficiency is usually very low (5-7 %), only for the hydrogen organisms an efficiency of about 25 % is found. Apart from the aerobic organisms, there exists a number of anaerobic autotrophs. All these reactions have in common the generation of hydrogen, which, in this case, is accepted by oxygen, enabling other hydrogen to reduce CO_2. This takes place directly in *Hydrogenomonas* according to $4H + O_2 \rightarrow 2H_2O + 112{,}000$ cal. For the other chemosyntheticates we may write, in the sequence of the number of hydrogen-atoms generated:

Table 4.4 Free energy efficiency of bacteria in oxidation with various inorganic acceptors. After Baas Becking and Parks (1927).

	Reaction		Efficiency
1. Iron bacteria	$Fe(OH)_2 + H_2O \rightarrow Fe(OH)_3 + H$	1	<1%
2. Carbon monoxide	$CO + H_2O \rightarrow CO_2 + 2H$		
3. Thiosulphate	$H_2S_2O_3 + H_2O \rightarrow H_2SO_4 + S + 2H$		
4. Hydrogen sulphide	$H_2S \rightarrow S + 2H$	2	5%
5. Nitrite	$HNO_2 + H_2O \rightarrow HNO_3 + 2H$		
6. Sulphur	$S + 4H_2O \rightarrow H_2SO_4 + 6H$	6	9%
7. Ammonia	$NH_3 + 2H_2O \rightarrow HNO_2 + 6H$		
8. Methane	$CH_4 + 2H_2O \rightarrow CO_2 + 8H$	8	15%

Now the free energy efficiency of the above forms, as calculated by Baas Becking and Parks (1927) show that the hydrogen bacteria are the most efficient, followed by the methane oxidation, sulphur and ammonia oxidation, while the iron bacteria have a very low efficiency. This efficiency seems to be proportional to the hydrogen yield. Geochemically one can say that the reactions which occur in nature with development of energy (exothermic reactions will find its counterpart, an organism, which makes use of that energy). The presence of a certain organism may therefore be predicted. The presence, however, of the carbon organism has not been proved and the bacteria that lives on 'gas-leaks', in laboratory air, Beijerinck's *Bacillus pantotrophus*, that should oxidise CO, is probably not a *Bacterium*, but an *Actinomycete*. Most of the autotrophs mentioned here are facultative autotrophs. Even the extreme autotroph *Nitrosomonas* will live, according to Kingma Boltjes on Heyden-Nährstoff (Kingma Boltjes, 1934).[68] As far as the CO_2 is concerned all inorgoxidants are inorgreductants. Now there are facultative heterotrophs as well *e.g., B. soli*[69] and *Sporovibrio desulfuricans*, which forms may persist on hydrogen as an only energy source (D. Stephenson).[70] A systematic survey of the process of heterotrophs to reduce CO_2 in the presence of hydrogen has, as yet, not been made. Hes has shown, that CO_2 is probably indispensable in alcoholic fermentation of glucose! What biochemical consequence one should draw from this fact is, as yet, obscure (Hes, 1937).

Text box 4.2 – Baas Becking notes made prior to writing the manuscript

G. Harmsen (dissertation) on aerobic cellulose decompose (in press).[71]

Cell-vibrio. 2. *Cytophaga* (*Myxococus*?) 3. *Polyangides* (*Myxobact*.) (*Sorangium, Archangium*). 4. Bacilli (+ endospores) = Vibrio + spore! 5. *Actinomyces* and *Micromonospora*. 6. *Protoactino*[*myces*] and *Mycobacteria* = *Corynebacterium*.

66 Winogradsky (1922) introduced the term "anorgoxydant".

67 A reference to Henry James Bunker (1897-1975).

68 T.Y. Kingma Boltjes (1934) found that the classic "Nährstoff-Heyden", an egg albumen preparation, resulted in better growth of both *Nitrosomonas* and Nitrobacter colonies on agar plates.

69 Present name *Microbacterium soli*.

70 Majory Stephenson (1885-1948), British biochemist, who wrote the classical textbook *Bacterial Metabolism* in 1930 (Stephenson, 1930). Baas Becking referred to Stephenson and Strickland (1931).

71 Baas Becking referred to the Groningen PhD thesis of George Wilhelm Harmsen (1946).

4.8 Dependent Organisms

A.J. Kluyver and his school have shown that the line of demarcation between autotrophs and heterotrophs is anything but sharp. A suitable hydrogen donor suffices in most cases whether organic or inorganic in nature makes little difference. However, we should not go so far as to say that no real difference exists between the two realms. As the whole the autotroph may also feed on organic compounds, but the reverse is usually not the case, only in special instances (experiments of M. Stephenson with sulphate reducers) success has been obtained.[72] It seems therefore that most organisms are really dependent. It may be worthwhile to investigate the nature of these dependences. In the primitive concept of the cycle (Liebig) there is only question of "food". Later the energy transaction when also considered. It may be well to classify the power and the want of the living cell.

1. The synthesis of glucose.
2. The breakdown of large molecules, yielding glucose.
3. The breakdown of glucose and energy release.
4. The synthesis of the specific protein and of the protoplasm.
5. Synthesis of substances with special (*e.g.*, morphogenetic) function.

These are few organisms, and all of the these belonging to the Plant Kingdom, that are capable to perform all of these feats. From this it appears that the whole pattern of living nature is held together by exchange of substances that gradually "nothing in the world is single" (Shelley; also treated in Section 1 and Section 7.1).

Thus far, organisms were studied chiefly as entities, separate, specific, independent things. It is well to realise that biology cannot be understood by such limitations. Let us test our own power and limitations.

1. We cannot synthesise glucose; therefore, we need organic food.
2. We cannot make use of cellulose; we can use starch.
3. The breakdown of glucose we perform, but we cannot synthesise ascorbic acid, which we derive out of our food.
4. Synthesis of proteins we can perform, although we need preformed acid, moreover we need certain amino acids which we cannot synthesise.
5. We cannot perform the synthesis of a great many substances with specific morphogenetic function or of functional importance. Visual purple needs plant carotene, fertility hormone comes from wheat-germ *etc*!

The dependent organism after having built its body at the cost of others will leave this body sooner or later to the action of microbes. These microbes will mineralise it more or less completely which means that the carbon compounds will all disappear but there may remain something that will form coal or oil. In this way, from the mineral world the plant will emerge and synthesise glucose. But one shouldn't forget that the richness of the soil is not only mineral (fertiliser problem). Every single microbe in the cycle may contribute an organic minimum substance which substance, as we know is capable of action in very small quantities, in high dilution. Therefore, if organic matter is mineralised, practically all of its carbon has been organic remnants, the nature of which we only may surmise and which make the soil or the water to a very complete biological entity indeed. Even in our C, P chemicals traces of the compounds may occur (asparagin!) and so influence experimental results! The question of the independent organism has not been solved.

4.9 Life Cycles

4.9.1 Introduction

Jan Swammerdam in his *Biblia Naturae* was really one of the first to make us realise the dramatic sequence of larva, pupa and imago in the insect world and of the frog. It appeared that the animal changed its milieu several times. Swammerdam's attempts to homologise the life cycle of the carnation with that of the frog was not so very lucky![73] It took more than two full centuries before the life cycle of the higher plant was finally fully understood (Strasburger, Nawaschin),[74] In relation to the milieu, it seems well to consider the life cycle of living beings, especially those that involve a change in mode of life, where an aerial or terrestrial organism alternate with an aquatic. But there is another alternative, of less obvious nature, but equally fundamental, which should be dealt with first.

4.9.2 Alternating generation

The fertilised egg cell or zygote. Z in the diagram (Fig. 4.15), gives rise to an organism with the double (2 n) number of chromosomes. This diploid being shows cells, when mature, which undergo so called maturation – or reduction division – by which process (R in the diagram) the number of chromosomes is back to n (n generation or haploid generation). Male and female sex cells are both haploid, and again give rise to a zygote. Now in nature diploid and haploid, inevitably following one another, are not equally represented in the life cycle of one organism. There are algae (A in diagram) where the diploid phase is brought back to one cell (*Spirogyra*). There are also organisms where the haploid phase is brought back to one cell (C) as in higher animals. In various algae, but

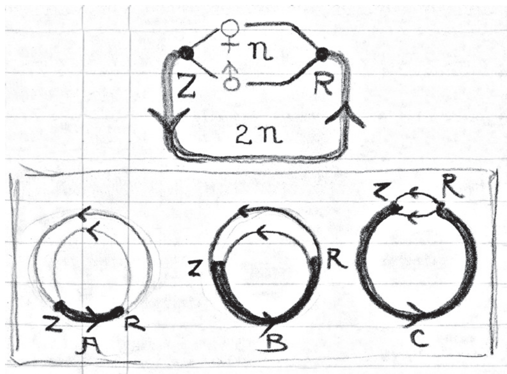


Figure 4.15 Schematic representations of the life cycles of various organisms: Z = zygote R = reduction division of sex cell.

72 In the preceding section Baas Becking referred to 'D. Stephenson', he called her also 'Dorothy' instead of 'Marjory'.

73 Jan Swammerdam (1637-1680), Dutch microscopist famous by his anatomical research of the life of insects. Swammerdam included an engraving showing the stage by stage development of a frog and a carnation, pointing out the similarities in the process of growth. Tabula XIII in: Johannes Swammerdam, *Historia Generalis Insectorum* (Swammerdam, 1669).

74 Eduard Adolf Strasburger (1844-1912), Polish-German botanist, the first who provided an accurate description of the embryonic sac in gymnosperms and angiosperms along with demonstrating double fertilisation in angiosperms. Sergei Navashin (1857-1930) Russian biologist, who discovered double fertilisation in plants in 1898.

also in certain ferns, both generations seem to be about in equilibrium. The significance of the reduction division in the preparation for sexual activity, the significance of the sexual act has in this "new deal" of the chromosome map in the zygote.

4.9.3 Concomitant phenomena in zoology

In the higher plant the haploid generation is reduced to few cells, in the higher animal even to one cell of each type, sperm and egg. Amongst the great number of existing cases only mention the life cycle of the honey bee (see Fig. 4.16). The queen is only a diploid worker which, in contrast with other workers became fertile by special food (vitamin E!?) The queen is fertilised only once, on the wedding flight. The sperm she keeps in a pouch and may at will fertilise an egg (in which case a worker larva appears) or lay it unfertilised, in which case a drone larva is hatched. The drone is therefore a haploid, and the generation of its sperm does not take place by means of a reduction division.

(About sex determination and sex chromosome see T.H. Morgan).[75]

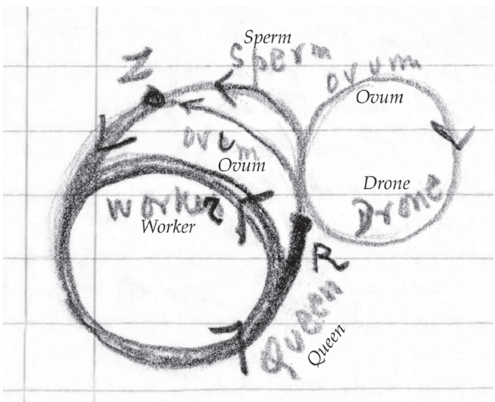


Figure 4.16 Schematic representations of life cycle of the honey bee, showing the reproduction of the queen, worker and drone.

4.9.4 Cytology bacteria

(Paravicini, 1918; Löhnis, 1921; Henrici, 1939). There are the bacteria, and bluegreen algae and certain primitive protozoa which lack a nucleus and (therefore?) seem to lack sexual reproduction. It is claimed that these organisms, at least the bacteria also show a certain life cycle, whether genetically induced or caused by the milieu remains unanswered. In Figure 4.17 a long spirillum (1) may disintegrate into small particles (2, 3), and the particles may give rise again to a complete spirillum (4, 5). For higher fungi this reminds us of the theory of Grierson [?] now quite dead![76] As a great many non-spore forming bacteria seem to persist in the most unlike places, and the vegetative state of these organisms is most susceptible to adverse conditions, indirect evidence of such a "bacterio-zyklogenesis" be presented. Whether it is conclusive remains very doubtful.

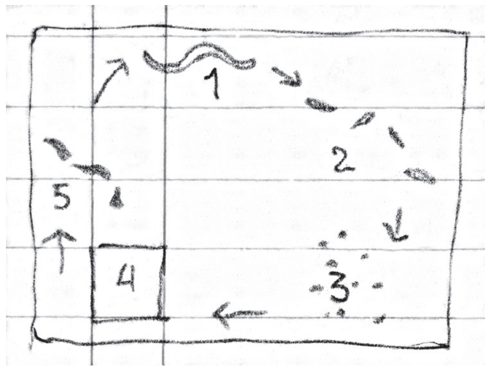


Figure 4.17 Suggested life cycle of bacteria, algae and protozoa.

4.9.5 Life cycles and ergones (parasites)

The most complicated life cycles we find in parasites. Here we often meet with five or more stages and five or more hosts *e.g.*, fly-copepode-snail-fish-man. It is probable that parasites are highly in need of ergones, and that the whole 'bouquet' of ergones may only be supplied by an entire series of hosts. Parasites knit the web of life very close. The relation between cycle and milieu is most apparent here. On the life cycle of fishes, the beautiful example of the eel (Joh. Schmidt) should be given. Our European eel is hatched in the Sargasso Sea, first yields a so called glass-fish. The glass-fish is changed into a katadromic spike fish, which takes 1-2 years to become a monté, that means a fish with a hankering after freshwater. The monté swims into the freshwater. After 4-5 years the Dutch eel, when sexual maturity approaches, yearns for salt water, swims anadromically against the Gulf Stream to the Bahama's where it finally spawns.[77]

75 Possibly a reference to Morgan (1909). See also Abbot, Nordén and Hansson (2017).
In 1919 and 1920 Baas Becking and his wife worked some time during the evenings to prepare a series of microscopic preparations of *Drosophila* for T.H. Morgan and C.B. Bridges research programmes.
When Baas Becking returned to the Netherlands in 1921 to obtain his doctorate from Utrecht University, he had brought home made preparations of *Drosophila melanogaster* with him, which made a deep impression. In this country there was still a lot of doubt about the correctness of Morgan's theory that the genes in the chromosomes are linearly arranged and that factor coupling involves genes located in the same chromosome. Due to the potential for crossover between homologous chromosomes during reduction division, the degree of linkage would be broadly inversely proportional to the distance between the genes in the chromosome. This doubt arose mainly from the opinion that Morgan depicted the chromosome array of *Drosophila* in an improper schematic way. The contrary was unequivocally evident from Baas Becking's preparations, which made the doubters change their minds (Translated from Dutch AJPR).
See Koningsbergen (1963) also *Algemeen Handelsblad* (4 juni 1921, p. 3).

76 Grierson not identified. Baas Becking probably referred to the reproduction of some of the most complex fungi (*e.g.*, mushrooms) that do not develop differentiated sex organs; rather, the sexual function is carried out by their somatic hyphae, which bring together compatible nuclei in preparation of fusion.

77 Reference to Johannes Schmidt (1877-1933), Danish biologist credited with discovering that eels (*Anguilla anguilla*) migrate to the Sargasso Sea to spawn: *The Breeding Places of Eel* (1923).

4.9.6 *Antithetic alteration*

(Hofmeister, Bower, Campbell).[78]

[Baas Becking inserted Fig. 4.18.]

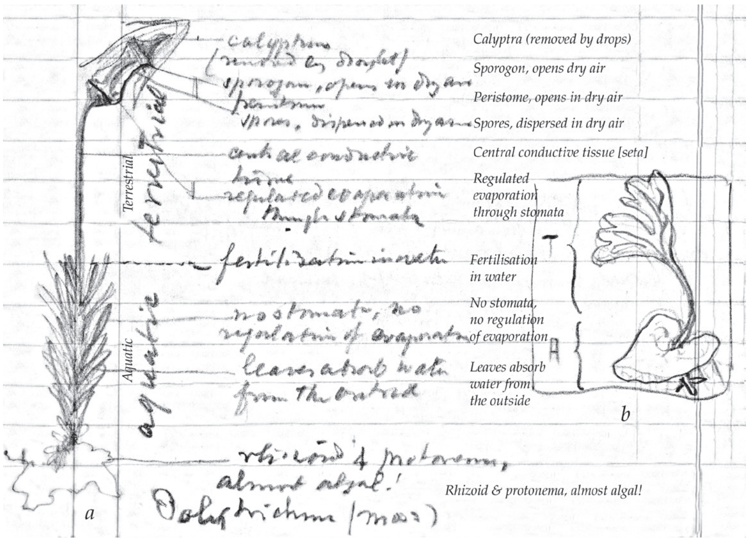


Figure 4.18 **(a)** Life cycle of *Polytrichum* (haircap or hair moss). **(b)** Life cycle of ferns (A = Aquatic, haploid generation; T = Terrestrial, diploid generation).

In mosses and ferns, the alternating of generations goes hand in hand with the alternating of biological character, land plant and aquatic alternating. This process is illustrated in the figures, it will be seen that in the fern both generations are mutually independent and in equilibrium.[79]

4.9.7 *Life cycle of Ctenocladus circinnatus*

(Ruinen, 1933, thesis).[80] Although the details of the case escaped me, I remember this piece of beautiful analysis of stages in the life cycle in their dependence on milieu (Fig. 4.19). Alkalinity, temperature and salinity of the water all playing a role to induce various modes of growth or of reproduction to be followed. The alga in question is a cosmopolitan (Italy, Russia, Australia, California) occurring in alkaline, saline desert lakes of not too high a temperature. By the study of life cycle and milieu Ruinen (1933) could predict its terrestrial distribution.

4.9.8 *Death*

(Minot).[81] Here we meet with an irreversible process, there had been much waste in the cycle, thrown aside. Now the thing itself is waste and enters into the cycle of matter. Potentially immortal is the protozoön (Woodruff),[82] and the unicellular plant, immortal is the "Keimbahn" of the higher organisms. In death, when there are organs, agony sets in with the disturbance of their correlation, then the organ dies, later the tissue, later the cell. In *Paramecium* first the longitudinal cilia, then the transversal and finally the oral ceases to beat,[83] never in movement the animal first rotates and this only around the pulsatorisation [inserted: On death and dehydration, also *cf*. recent book of Boeke, 1941.][84]

78 Hofmeister, Wilhelm Friedrich Benedict (1824–1877), German botanist. His first work was on the distribution of the *Coniferae* in the Himalaya, but his attention was very soon devoted to studying the sexuality and origin of the embryo of *Phanerogams*. His contributions on this subject extended from 1847 till 1860, and they finally settled the question of the origin of the embryo from an ovum, as against the prevalent pollen tube theory of M. J. Schleiden, for he showed that the pollen tube does not itself produce the embryo, but only stimulates the ovum already present in the ovule. He soon turned his attention to the embryology of *Bryophytes* and *Pteridophytes*, and gave continuous accounts of the germination of the spores and fertilisation in *Pilularia*, *Salvinia*, *Selaginella*. He published in 1851, *Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen* (Hofmeister, 1851). This work will always stand in the first rank of botanical books. It antedated the *Origin of Species* by eight years, but contained facts and comparisons which could only become intelligible on some theory of descent.
Frederick Orpen Bower (1855-1948) was a renowned botanist best known for his research on the origins and evolution of ferns. Appointed Regius Professor of Botany at the University of Glasgow in 1885, he became a leading figure in the development of modern botany and the emerging field of palaeobotany, devising the interpolation theory of the life cycle in land plants. *The Ferns* (Bower, 1923-1928) was the first systematic classification of ferns according to anatomical, morphological and developmental features. In this three volume work Bower analyses the major areas of comparison between different species, describes primitive and fossil ferns and compares these species to present day fern species, providing a comprehensive description of the order.
Douglas Houghton Campbell (1859-1953), American botanist known for his research concerning modes of sexual reproduction in mosses and ferns. He was Baas Becking's PhD supervisor in Stanford University in 1919-1921.

79 Using Figure 4.18, Baas Becking gave a very brief summary of the life cycle of the haircap moss life. Sexual reproduction takes place when the male gametophyte (haploid) releases sperm cells that are caried on splashing water droplets to neighbouring female plants. Chemical attraction ensures the sperm cells find the egg within the female archegonia. The fertilisation produces the sporophyte (diploid), which consists of a foot, stalk and capsule. The capsule is a small pod that contains the spores (haploid) and it is closed by the calyptra that is removed by waterdrops. On the front of the capsule are a set of teeth, called peristome that controls the release of the spores. The spores grow out as a thread-like chain of cells, protonema or rhizoid, the earliest stage of development of the leafy haploid gametophyte.

80 In *Geobiologie* (1934), Baas Becking identified *L. siberica* as *Ctenocladus circinnatus* Borzi.

81 Charles Sedgwick Minot (1852-1914), American anatomist and embryologist at Harvard Medical School. Baas Becking referred to Minot (1891), Minot (1908). In the 1953 manuscript of *Geobiology* he remarked (p. 132):

> A modern treatment of the problem of senescence and death, after Minot's classical contributions (1891, 1907) would be welcome to many.

See also Mills (2012).
It is remarkable that Baas Becking (1953a) did not refer to Minot in his lecture *The Nature of Death* for the Sydney University Biological Society in July 1953. He concluded his lecture:

> Life itself is a megachronic phenomenon, like the earth, the solar system and the universe. Life has fought on all planes, almost down to the leptochronic (the divisions given are more or less arbitrary). Death is nothing in itself. It is a term, describing the transition from the highest organisation form of matter to the molecular. Life is an intricate, developing pattern of molecules and ions, death is shapeless. Beauty's rose is a phenomenon of astronomical magnitude, not only as far as the time element concerned, as I have tried to elucidate from this same place two years ago. Thus far life has been persistent on this planet. Let us hope that our species will not be a great contributary cause to the death of the thin and vulnerable green living veil of this earth; to sustain life is more precious than the cheap act of making life cease. I cannot agree with a great poet [Percy Bysshe Shelley], who said:
> How wonderful is Death, Death and his brother Sleep.
> one should not meddle with great poems, but I am tempted to say, at this place
> How wonderful is Life, Life and his father, God.

82 Reference to Lorande Loss Woodruff (1879-1947) and his associates at the Yale Zoological Laboratory who published vastly on *Paramecium* from 1907 to 1945. Woodruff maintained that his 'Methuselah' strain of *Paramecium aurelia* for many years and for thousands of cell generations and could perpetuate itself indefinitely as long as new substances were introduced into the nutrient fluid in which they were placed. Baas Becking possibly referred to Woodruff's *Foundations of Biology* (Woodruff, 1922). The book inspired Sigmund Freud in his *Beyond the Pleasure Principle* (Chapter 6).

83 According to Takagi, Kitsunezaki, Ohkido and Komori (2005):

> *Paramecium* cells stopped swimming, although cilia all over the cell surface continued to beat. Sometimes cells that stopped forward or backward swimming rotated at the resting position. This made it easy to observe the subsequent processes leading to death. Cilia on a part of the cell surface continued to beat until the moment of cell rupture, and sometimes continued to beat after the cytoplasm began to flow out.

84 Dr. Jan Boeke (1874-1956), Professor of Histology and Embryology, Utrecht University. Reference to Boeke (1941). See also Heringa (1961).

Death is of great importance to Geobiology. Mass death, the explosions mortelles a counterpart of the explosion vitale. It is perhaps rarer than geologists assume (Richter, 1931) on the Hunsrückschiefer,[85] euxinic phenomena (see Section 7.6.4).[86] About the further analysis of death and the longevity of organisms the special literature should be consulted.

4.10 Cosmopolitans

4.10.1 Introduction

It seems in flat contradiction to our thesis "everything is everywhere" to talk about cosmopolitans. All organisms should be cosmopolitans. However, there are impediments, as we have seen to distribution, and the cosmopolitan is the organism with unlimited power of dispersal. It should also be more or less of a living biont, for if it were choosy, it would be everywhere in latent stage, but not present as a growing

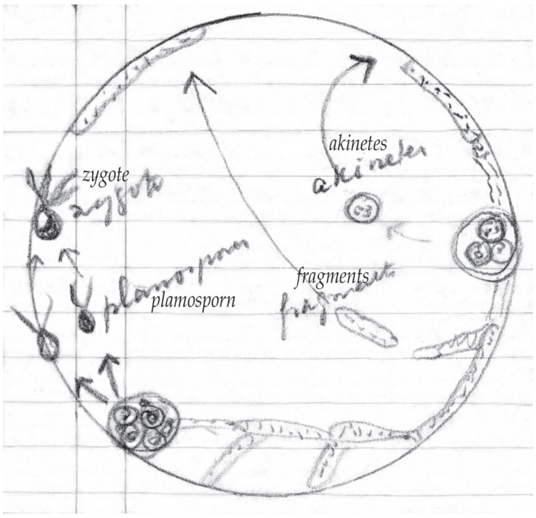


Figure 4.19 Baas Becking's version of the Life cycle of *Ctenocladus circinnatus*. After Ruinen (1933).

organism all over the earth. Cosmopolitans should be really the organisms that would accompany the earth longest through its various adventures. They should stick longest to the terrestrial environment. They embrace representatives of nearly every class, lower and higher. Of course, at least the higher forms are a familiar lot!

4.10.2 Natural and terrestrial milieu

In our days a great many organisms have been distributed by man. They often find what are apparently congenial surroundings. We shall mention them haphazardly. *Petricola* [*pholadiformis*], borer worm, from N. America, all over the sea in N. Europe. Also, *Dreisena*, a mollusc and *Eriocheir* [*sinensis*], the Chinese wool crab. Franciscus Padre's brought *Avena fatua* [common wild oat] to California, together with a mass of other weeds. *Eichornia crassipes,* the water hyacinth from N. America is now over all the tropical world.[87] From the Leyden Botany Gardens there has been introduced the water fern *Azolla* [duck weed] from N. America, now over N. Europe. From Mexico *Opuntsia*, all over the Mediterranean and particularly [*O.*] *stricta* in Australia, where it could only be killed by bacteria! [88] Well known is the increased distribution of rat and opossum on and of the jack rabbit and fox in Australia. In the tropics very few plants one meets at the wayside are autochthonous. In the case of Javanese weeds, *e.g.*, kerinjore *Eupatorium pallescens* from which vegetation also *Lantana camara*. We could continue to give anecdotical examples but enough is given to illustrate the fact that natural and terrestrial milieu are by no means identical for many higher organisms.

4.10.3 Bacteria

It is safe to assume that bacteria are perfectly cosmopolitan in their distribution. This is rather obvious where spore formers are concerned, but it remains a mystery that forms like the purple *Spirillae*, of which we know no resting stages, are so perfectly distributed in any material we may employ as infection. I remember the time when we made excursions to the good growth of iron and sulphur bacteria. The knowledge of the milieu has given the means to raise them in the laboratory. In certain instances (*Azotobacter*) the four new minimum metals (molybdenum) to obtain development. Ignorance of those facts may lead to erroneous statements. Of course, there are common and rarer forms, for instance, the pathogens. But the man culture method works without failure everywhere and so shows the cosmopolitan distribution of bacteria.

4.10.4 Other microbes

Ruinen (1933, 1938a, 1938b) and the author (Baas Becking, 1928b) have demonstrated the universal distribution of salt loving ciliates, flagellates and amoebae. The protozoa fauna of the lakes in N.W. Victoria, South Australia, Madura (Dutch East Indies), Bombay, Egypt, California, Portugal and Italy proved to be very similar. So similar, in fact that most differences should be ascribed to influences of the outer milieu. Also, the freshwater forms are similar the world over. When we compare the algae from the N. American by G.M. Smith (1933), with that of the British flora of F.E. Fritsch (1927), the difference is slight. Marine diatoms are equally cosmopolitan. Elsewhere in the book we mentioned *Aulacodiscus kittonii* Arnott, a form descended from the Congo River mouth and found by us in N.W. Washington, at the mouth of the Columbia River, and one year later at Corinto,

85 Richter (1931), *Tierwelt und Umwelt im Hunsrückschiefer; zur Entstehung eines schwarzen Schlammsteins*. The Hundsrückschiefergruben near Bundenbach and Gemünden is one of the most important places in Germany for fossils. Geologists assumed that anaerobic conditions and high content of H_2S in the former Hunsrückschiefesmeer resulted in a catastrophic mass death. Baas Becking referred to Richter, who concluded (p. 311):

> Die im Hunsrückschiefer erhaltene Tierwelt hat ihre Ausgewachsenheit mit normalen Lebensaussichten erreicht und zeigt keinerlei Anzeichen von ungewöhnlichen Todesfällen der Einzelnen, noch chemisch mechanischen Massenunfällen.

86 Euxinia or euxinic conditions occur when water is both anoxic and sulphidic. This means that there is no oxygen and a raised level of free hydrogen sulphide.

87 Reference to the missionaries of the Order of Friars minor founded by Francis of Assisi (1181/82-1226).

88 *Opunitia stricta*, the Spiny Pest Pear, was introduced in Australia mid-1800s. By 1925 the prickly pear had spread across about 25 million acres of Queensland and New South Wales. The most successful method of eradicating the prickly pear was introduced in 1926 with the release of the South American cactus moth, *Cactoblastis cactorum*, in Australia. Bacterial killing of the *Opuntia* was not found in literature. In the 1953 version of *Geobiology* Baas Becking referred to the successful introduction of *Cactoblastis* (p. 748).

Nicaraqua.[89] Dinoflagellates, silicoflagellates also belong to the cosmopolitans. For the *Foraminiferae* see Cushman (1928), Schenck (1928),[90] van der Vlerk.[91]

4.10.5 Algae and fungi [and higher plants]

4.10.5.a Algae and fungi

H.R. Sinia, at the Botanical Lab at Leyden cultured dune sand in culture solution at a temperature of 30 °C.[92] To his surprise he raised several tropical forms, that were apparently present in latent form but could not develop in the infra-optimal temperatures. E. de Wildeman,[93] in *Algae Flora of Buitenzorg, Java*, shows, moreover the general cosmopolitan nature of most of the green freshwater algae (as far as the *Phaeophyceae* [= brown algae] are concerned, real marine forms, seem to be geographically fixed for some reason or other. At least the forms in Holland, Java, Karachi, Sargasso Sea, Nicaragua, California, Celebes and South Australia are all different. With higher fungi Lütjeharms[94] and also Boedijn[95] find a great number of cosmopolitans. Many tropical non-fruiting mycelia are common European species (Rand).

4.10.5.b Higher plants

Molisch (1921?) described the agricultural weeds from all over the world. Of course, here man has taken a hand, but there are other plants cosmopolitan, not transported by us.[96] In the first place *Pteridium aquilinum*, the bracken. The author found bracken in California, Washington, Nicaragua, Salvador, Java, Celebes, S. Australia, Victoria, Scotland, England, Holland, Belgium, France, Germany. It hardly can be otherwise or the spores are universally transported by wind. It is one of the most conspicuous of the cosmopolitans. *Ruppia maritima and rostellata* [= beaked tasselweed], an aquatic, occurring chiefly in brackish water. The author found it Bay of San Francisco, California, York Peninsula, S. Australia, the island of Madura, near Java, near Bombay, British India, near Setubal, Portugal and the island of Terschelling, Holland, dispersal through water (?). *Lantana camara* [= common Lantana] is a Hawaiian *Verbaenaceae* plant which has conquered the entire tropics, new and old from Congo to Hindustan and points west. *Senecio vulgaris* [= groundsel], *Bellis perennis* [= common daisy], *Poa annua* [= annual meadow grass], *Plantago media* [= hoary plantain] belong to the white man's trail. The book of Molisch, mentioned above, should be consulted.

4.10.6 Higher animals

Housefly
Rabbit
Sparrow

4.10.7 Summary and conclusions

[Baas Becking left this section blank.]

89 See also Baas Becking (1934), Chapter IX p. 94 (2016 version).

90 Joseph Augustine Cushman (1881-1949), American geologist, palaeontologist and foraminiferologist.
Hubert Gregory Schenck (1897-1960), specialist in micropalaeontology and Professor of Geology at Stanford University.

91 Isaäk Martinus van der Vlerk (1892-1974) Dutch geologist and palaeontologist. See den Tex (1974).

92 Hiddo Rinse Sinia (1910-2000), biologist. His PhD thesis in University Zürich was Sinia (1938), *Zur Phylogenie der Fiederblätter der Bursaceeen und verwandter Familien*. In 1939 he worked as a volunteer in the Leiden Herbarium and made an inventarisation of the collections present as samples. After WWII Sinia worked some time in the Buitenzorg Botanic Garden. In *Geobiologie* (1934), Chapter II, Baas Becking referred to Sinia's experiments with soil algae from Meyendel (2016 edition, p. 13).

93 Émile Auguste Joseph de Wildeman (1866-1947), Belgian botanist and phycologist, pupil of Leo Erréra in Brussels. He published in 1900, *Les Algues de la Flore de Buitenzorg: Essai d'une Flore Algologique de Java*.

94 Dr. Wilhelm Jan Lütjeharms (Alkmaar 1907-1983), mycologist, chief assistant at the Rijksherbarium, Leiden. In 1936 Lütjeharms defended in Leiden his PhD thesis. In June 1937 Lütjeharms published in *Tropische Natuur*, *Over de duinen van Parangtritis ten zuiden van Djokja*. In 1937 he was appointed Professor of Botany at the University of Bloemfontein (South Africa) (*De Maasbode* 22-10-1937). According to Professor H.J. Lam (Jacobs, 1984, p. 115):

> All in the greatest excitement. Flags from both the buildings Leiden Herbarium and Leiden Botanical Laboratory] (on Lou (Baas Becking)'s insistence. I found it less necessary). At coffee great procession from Bot. Lab. Singing Sarie Mareis and everyone with a Proteacea in his hand! Afternoon, party in restaurant De Beukenhof.

In 1962 he became Professor of Botany at the British University in Capetown (*De Tijd en Maasbode* 31-03-1962). See also van Steenis-Kruseman and van Steenis (1950, p. 333).

95 Karel B. Boedijn (1893-1964), Dutch botanist and mycologist. Assistant of Hugo de Vries in the Amsterdam Hortus Botanicus. PhD 1925, *Der Zusammenhang zwischen den Chromosomen und Mutationen bei Oenothera lamarckiana*. In 1928 mycologist in Buitenzorg. Published in 1929, *Beitrag zur Kenntniss der Pilzflora von Sumatra* (Boedijn, 1929). Professor, Medical High School in Batavia in 1935. Professor, University Indonesia in Bogor until the 1950s.

96 Reference to Hans Molisch (1856-1937), possibly to his *Pflanzenphysiologie* (1921).

5. INFLUENCE OF THE MILIEU UPON THE ORGANISMS

5.1 Growth Curve

5.1.1 Introduction, the "overhanging"fate"

The living mass of one organism, or a population seems to increase according to a special law. The increase is often first fast, then slows down, until growth stops. There seems to be for the organism and for the population a limit which is slowly reached. Robertson compared the process to an autocatalytic reaction in which the reaction velocity dy/dt = y (a-y) in which *y* is the amount of substance transformed, and *a* the limiting amount of substance. Now in the case of organisms there is such a limit (obviously). It is not said, however, that organismal growth is a reaction with a single "master-catalyser." For population growth, however, the imputed limit seems very questionable. There should be an "overhanging" fate over a population, a sort of doom, represented in the *a* of the above differential equation. R. Pearl (1926) actually seems to suggest such a thing.[1]

5.1.2 Nature of the growth curve[2]

The equation of the hyperbolical tangent is (Kavanagh and Richards, 1934),

$$y = \frac{(e^x - e^{-x})}{(e^x + e^{-x})}$$

really the general expression of the "autocatalytic" population curve of T.B. Robertson and of Raymond Pearl. For if we take a population curve:

$$y = \frac{1}{(1 + e^{-x})}$$

and we write:

$$\frac{z}{2} = \frac{1}{(1 + e^{-x})} - \frac{1}{2}$$

shifting the coordinates, we obtain, for the right hand expression:

$$y = \frac{(e^x - e^{-x})}{(e^x + e^{-x})}$$

For the Robertson curve:

$$y = \frac{1}{(1 + e^{-x})}$$

we determine the first derivative as

$$\frac{dy}{dx} = \frac{e^{-x}}{(1 + e^{-x})^2} = \frac{1}{(1 + e^{-x})} \cdot \frac{e^{-x}}{(1 + e^{-x})} = y(1 - y)$$

the second derivative gives:

$$\frac{d^2y}{dx^2} = \frac{e^{-x} - e^{-2x}}{(1 + e^{-x})^3}$$

the third derivative:

$$\frac{d^3y}{dx^3} = \frac{(e^{-2x} - 4e^{-x} + 1)}{(1 + e^{-x})^6}$$

Now the first derivative represents an optimum curve, maximum at z = 0, points of inflection at the values for x in:

$$e^{-2x} - 4e^{-x} + 1 = 0$$

or,

$$e^{-x} = 2 \pm \sqrt{3}$$

$$x = \frac{-\log(2 \pm \sqrt{3})}{\log e}$$

[Baas Becking inserted Fig. 5.1. with the Kavanagh and Robertson and Pearl sigmoid growth curves.]

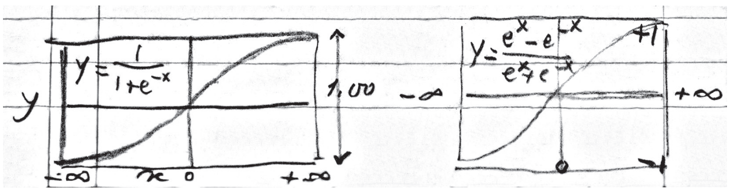


Figure 5.1 Kavanagh and Robertson and Pearl growth curves.

5.1.3 Consideration of H. Mark on the growth of large molecules

In his book, *The Chemistry of Large Molecules* (1939) Mark gives examples of the growth of polymers.[3] This is a case from inanimate nature much closer allied to our problem as catalyst reactions. Mark finds too a few cases that this growth may be represented by F-shaped curves. In the majority of cases hollow, or linear relations appeared. It follows that already here conditions are very complex and elude analysis. Therefore, in growth, where conditions are so much more involved, it is very risky, like Pearl does, to dictate a certain shape to a curve which obviously does not possess it!

1 Baas Becking probably referred to Pearl (1926, *The Biology of Population Growth*). Raymond Pearl (1879-1940), American biologist and T.B. Robertson, a physiologist. He published in 1908 two articles applying the logistic curve to various cases of individual growth in animals, plants and man (Robertson, 1908). The logistic curve was introduced by Raymond Pearl and statistician Lowell Reed in 1920, unaware of Robertson's earlier work. Pearl promoted the sigmoidal curve as a description of human and animal population growth. In subsequent years it underwent a barrage of criticism from statisticians, economists, and biologists, a barrage directed mostly against Pearl's claim that the logistic curve was a law of growth. Nevertheless, it emerged in the mid-1930s as a central model of experimental population biology, and in its various modifications has remained an important part of modern population ecology.
See Kingsland (1982), Kingsland (1995).
In the 1953 version of *Geobiology*, Baas Becking (1953a) discussed the work of Raymond Pearl in Chapter VIII, Section 10 *Human Population*, p. 754-759.

2 Baas Becking (1946a) described a number of sigmoid curves and their application to data of growth of pumpkins, rats and yeasts, growth of baby's (weight) and man (length) and population increase. The cases are described, the biological comments are not summarised in the final conclusions. He wrote about sigmoidal growth:
> Unless organisms have second sight, it is hard to conceive how the sigmoid should possess a predetermined upper limit for y or, in other words, when we do not want to accept an entirely predestined milieu, the sigmoid, as originated from the logistic expression, loses its biological meaning.
>
> He also stated that
>
> Goodness of fit of a certain expression to a certain set of experimental data does not mean that those data actually are connected by a law which is expressed by the equation of the curve which is tried.

In the 1953 manuscript of *Geobiology* Baas Becking wrote a comprehensive Section on *Organisms as a Function of Time* (p. 118-133).

3 A reference to Herman Franz Mark (1895-1992), Austrian chemist, 'father of polymer science', who escaped from Nazi Europe in 1938 and came to the Polytechnic Institute of Brooklyn. Baas Becking referred to *The General Chemistry of High Polymeric Substances* (Mark, 1940). The book was discussed by G. Salomon in *Chemisch Weekblad*, (February 8, 1941, p. 68-69). July 5, 1944, Mrs. T. Niekerk-Blom supplied him with a copy in the Utrecht *Kriegswehrmachtgefängnis* (NIOD 214, nr 33).
See Morawetz (1995), Deichmann (2001, p. 181-187).

5.1.4 Derivation from normal, ogive and other expressions

Now there are a great many similar curves. The integral of the normal curve

$$y = \frac{1}{(\sigma\sqrt{2\pi})} \cdot e^{-\frac{x^2}{2\sigma^2}}$$

is an example, the integral of:

$$y = \frac{ax}{(ax^2 + bx + c)}$$

and a great many other expressions the treatment of which here would require too much space. The author tried the goodness of fit of various population curves with twelve expressions and found only in a few cases a tolerable fit for the autocatalytic curve. This shows that the S-curve, being of very common occurrence, may have a *variety of causes*. This is also demonstrated by the fact that several distributions seem to fit the ascending branch, or the inverted descending branch of the normal curve. There is one case, however, where cause and effect has been studied (Baas Becking and Baker, 1926) and where the ogive, or rather the point binominal fits the observations most closely.[4]

5.1.5 Examples of natural growth curve, chiefly of populations

[Baas Becking left this section blank.]

5.1.6 Analysis

[Baas Becking left this section blank.]

5.1.7 Summary and conclusions

[Baas Becking left this section blank.]

5.2 Limits of Potential Milieu

5.2.1 Introduction

The laboratory milieu does not even distantly approach to the potential milieu, for the simple reason that it is impossible to delineate the potential milieu. The polyblepharid alga *Dunaliella* is able to live in 1 molar solution KCN. I only tried a limited number of compounds on *Dunaliella* and in how many organisms we tried the effect of a solution of 1 molar KCN? Therefore, we would rather be silent for want of facts if not, even at this stage of our science we might perhaps make certain generalisations. When we for example decimate the milieu of the filamentous alga *Chaetomorpha linum* in mixtures of 3 cations Ca, Mg, Na and three anions HCO_3, SO_4, Cl, we find its milieu optimum at a point which is not represented by any "terrestrial solution." The case seems to suggest a similar conclusion as the weird liking of *Dunaliella* for prussic acid. The relation of the *earth*, and its present geochemical condition and the organism is much lower than we had expected.

5.2.2 The factors rehearsed: properties of water, radiation

The chemical and thermal milieu are dependent upon water. For the chemical milieu "*corpora non agunt nisi solute*" hold,[5] and we have seen that thermal action on dehydrated cells is materially lessened. Therefore, the condition of water in the cell seems again to dictate. If a spore or a cyst were perfectly dry, perhaps it could start on an interplanetary trip, carried by radiation – pressure – as Svante Arhenius assumed. But radiation remains as an important agent. It remains to be seen whether the enormous intensity of ultraviolet, lethal radiation, effectively screened off by our atmosphere, would not kill anything, however dehydrated, that came under its influence! Henderson has called special attention to the thermal properties of water which properties caused this earth to process its lasting and equable climatic conditions. The gravitational field of the earth, finally determines the composition of atmosphere and hydrosphere. As a matter of fact, for our living beings in the "hydrosystem" (there is, as we have seen, also an ammono system), the earth is a pretty fine abode. But we should not forget that we are here because the conditions are so favourable, and that these conditions were not created to pleasure! (Whewell).[6]

5.2.3 Stenobionts

Stenobionts are very fragile organisms. They live within very narrow milieu boundaries. They live, to use the words of Robert Bridges (Testament of Beauty) "on the sharp of a razor, that may not e'en be blunted, lest they sicken and die."[7] Of a great many organisms, which we have only observed, but never experimented with, we suspect this stenobiotic nature. There are, for instance, mosquito larvae occurring in the liquid of the beaker of the insectivorous plant *Nepenthes* (*Tropische Natuur,* 1929).[8] We do not know whether there are stenobionts, only experiments will show. In relation to temperature J. Ruinen has investigated the green *Ulothichal* alga *Ctenocladus circinnatus*.[9] This alga is able to develop in a temperature range of 16-21 °C. This is a very narrow limit.

The tunny [also called 'tuna'] is a fish that cannot withstand temperatures lower than 14 °C. Many instances of flowering are to be ascribed to temperature influence in a previous developmental stage. Jarovisation (= vernalisation)

4 Baas-Becking and Baker (1926).

5 Corpora non agunt nisi fluida (or liquida) seu solute (Aristotle): Compounds do not react unless fluid or if dissolved.

6 Like in Section 3.5.1, Baas Becking referred to Rev. William Whewell (1794-1866).

7 In his lecture for the Sydney University Biological Society *The Nature of Death*, July 14th, 1953, Baas Becking also quoted Robert Seymour Bridges (1844-1930). He referred to *The Testament of Beauty: a Poem in Four Books* (Bridges, 1929).
Life is an improbable event. As Robert Bridges says; "it holds balance on a razor's edge, that may not e'en be blunted, lest we sicken and die."

8 Reference to Johannes Carolus van der Meer Mohr (1892-1969), entomologist, in 1925 assistant, and from 1934-1939 director, Deli Experimental Station Medan. Van der Meer Mohr (1929), Van der Meer Mohr (1931).

9 Reference to dissertation Jacoba Ruinen (1933) in which the species is named *Lochmiopsis siberica* Woron. This form is identical to *Ctenocladus circinnatus* Borzi. See also Baas Becking (1934 and 2016, p. 117).

of wheat is one of the examples here.[10] Many *Desmidiaceae* have a relation to the pH, occurring only in acid waters. For animals the relation to acidity is not so pronounced. The alga *Lochmiopsis* (*Ctenocladus*) mentioned also has a very remarkable saline milieu, being extremely calciphobic, alcalophilic and osmophilic up to 1 molar NaCl, beyond which the organism cannot exist. Its temperature milieu is even more limited akinetes germinate only between 16-20 °C.[11] Several organisms are closely fixed to the osmotic value of the marine environment, although there is more surmise and talk about this than experiment. The marine plankton crustacea *Evadne*, for instance, lives for days in distilled water![12] The most beautiful examples of stenobionts one finds in parasites. Even temporary ectoparasites like body lice, show already, a great conservation and apparently, have never left their host for millions of years (Ferris, *De Anoplura*).[13] How else to account for the fact that the louse of the camel and that of the llama are closely related? (see also Section 7). Stenobiontic life is therefore often closely related to dependent life, and the closer the dependence of an organism upon another, how narrower the milieu becomes.

[In the margin: A typical stenobiont is the alga *Hydrurus foetidus*, the water tail, only occurs in water with very little electrolyte. This as opposite to halophytic organisms which are, however often eurybionts (*Dunaliella*).]

5.2.4 Eurybionts

A real eurybiont one should not miss in extreme conditions of the milieu. Whether acid or alkaline, cold or hot, freshwater or concentrated brine, the organism should be there. When the earth should be heated up or cooled down, the eurybiont should keep the earth company to the bitter end. Let us see which organisms we find.

a. ***Bacteria.*** Sulphate reducing bacteria I found in a heather bog, pH 3.8, also in Searles' Lake, Nevada, pH 10.8. Under the ice we find sulphate reduction but also in the hot springs at Kali Pait (48 °C).[14] The bog water contained almost no minerals, while the solution at Searles' Lake was saturated. Cellulose bacteria and biologic acid *Closteridia* probably also fall under the eurybionts.

b. ***Protozoa.*** Amoeba we find everywhere, in very clear mountain water and in concentrated brine (Baas Becking and Ruinen) in Lake Tyrrell, S. Australia pH 8.8 and in Soda Lake Nevada pH 10.8.[15] In the hot springs of Kawah Tjiwedéh (Java) and in Mammoth Hot Springs, Yellowstone up to 58 °C. But also, in the cold ditch water collected over ice in January.

c. ***Bluegreen algae.*** Accompanying everywhere. Hof (1935) described them from brine and Beijerinck from bog water (1902).[16] They also occur in a pH range 3-11. In hot springs of Yellowstone van Niel found these up to 75 °C. In the lichens they occur in temperature of -40 °C.

d. ***Nematods.*** Apparently have a very wide milieu. There has hardly been any large sample of extreme milieu that did not yield one or more of these curious animals. They are worth investigation, especially those living in hot springs and in saturated brine (Australia, Lake Bumbunga).[17]

e. ***Fishes.*** It seems that, apart from certain flies that could be mentioned here, fishes are apt to withstand extreme milieu conditions. *Gasterosteus* lives in acid bog water without minerals, but also in an alkaline 10% NaCl solution. *Cottidae* live, according to Hecht, in a seawater entirely deprived of oxygen, and also in hot springs. *Cottidae* in Alaska are reported to have withstood solid freezing at -40 °C for a winter.

10 Vernalisation is the induction of a plant's flowering process by exposure to the prolonged cold of winter, or by an artificial equivalent. In 1928 the Russian agronomist Trofim Lysenko coined the term 'jarovisation' to describe a chilling process he used to make seeds of winter cereals behave like spring cereals. Later Lysenko inaccurately asserted that the vernalisated state could be inherited. During the 6th International Botanical Congress in Amsterdam in 1935 the Russian work on 'jarovisation' was discussed (*Proceedings* v. I, p. 158-160):

> There seems to be complete agreement in Russia as to the value of the method and it is there hailed, as one of the greatest advances in crop production yet made. Experimenters in other countries, however, have been much less enthousiastic and there is wide divergence of opinion as to its effectiveness.

Trofim Denisovich Lysenko (1898-1976), Soviet agronomist and biologist, responsible for subsuming biology to ideology. According to Andrei Sakharov in 1964:

> He was responsible for the shameful backwardness of Soviet biology and of genetics in particular, for the dissemination of pseudo-scientific views, for adventurism, for the degradation of learning and for the defamation, firing arrest, even death, of many genuine scientists.

See also Julian Huxley (1949), Borinskaya, Ermolaev and Kolchinsky (2019).

Apparently, Baas Becking was unaware of the scientific controversy over Lysenko's 'vernalisation'experiments. In his 1943 notes for *Geobiology* (1944) he summarised Lysenko's 1928 experiments (AAS 043 nr. 160-6):

> VERNALISATION applies to temperate wheat plants. Vernalisation is a technique by which flower production and fruiting is accelerated by application to the germinating grain if temperatures slightly above freezing point. […] Lysenko introduced his idea of "phasic development" of plants. […] The phenomenon of vernalisation is more complex than this and masks the focal point of two quite separate lines of investigations. One derived from Gassner's work on influences of temperature during germination; the other from the photoperiodic studies of Gardner, Allard and of Rasmund. Our knowledge of vernalisation has been advanced chiefly by the studies of O.N. Purvis.

O.N. Purvis and co-workers published six studies on vernalisation of cereals in the Annals of Botany 1934-1939. In his 1953 manuscript of *Geobiology* Baas Becking still quoted Lysenko as an authority (p. 430-431):

> The systematic investigation of periodic temperature sensitivity has led to the so called vernalisation of winter grains. These grains are normally sown in the autumn, as they need a cold period for the formation of flowers in the spring. Summer grains are sown in the spring and form ears without a previous cold period. Purvis (1939) has shown that summer rye differs in one dominant gene from winter rye. It is well known from work of Lysenko that winter wheat may acquire the characteristics of summer wheat if the seeds are subjected to a temperature of 3-10 °C for a few weeks. This vernalisation maybe applied to many other plants *e.g.*, potatoes, grapes, soybeans, vetches, maize, rye, red clover and sunflower. (Vernalisation Bulletin 1935).

See Purvis (1961) for review of his vernalisation studies, Gassner (1910), Gardner and Allard (1920).

11 Reference to PhD dissertation Jacoba Ruinen (1933; Figure 17, p. 780-781):

> The temperature range in which akinetes show rapid and intense germination is very narrow. The lowest limit lies at 14 ° C. At this temperature germination is reduced to a few percent, while growth has almost stopped. An optimum was found at 18 °C. Here germination occurred after a few days, the young plants were almost 0.5 mm. long. Growth seems still vigorous between 18°-21 °C., but here germination decreases markedly.

12 In *Geobiologie* (1934) Baas Becking referred to this finding in his laboratory in Leiden (p. 50, Eng. edition, 2016).

13 Reference to Gordon Floyd Ferris (1893-1958), American entomologist, Professor of Biology, Entomology at Stanford University (1912-1958). Baas Becking referred to Ferris (1916).

14 In the 1953 version of *Geobiology* Baas Becking wrote (p. 398-399):

> The most acid volcanic water on record is that of the Kali Pait, on the slope of the Idjen volcano, Java. Here no less than 216 mg H^+ was found *per* litre, corresponding to a pH of 0.66. the acid was […] mainly HCl. It should be remarked that certain bacterial sulphide oxidation may cause even higher acidities.

15 In the 1953 version of *Geobiology* (p. 399), Baas Becking referred to the tolerance of *Amoeba* in the hot spring in the volcanic water of the Javan Patuha:

> The high acidity seems to be no limiting factor either. Kawah Tjiwedéh on the slope of the Patuha in Java (temp. 42-85 °C), although the pH was below 2.0, was teeming with life, even an amoeba being present (see Ruinen and Baas Becking, 1938).

The reference to Kawah Tjiwedéh is also in Baas Becking (1938a), *On the Cause of the High Acidity in Natural Waters, especially in Brines*.

16 References to Beijerinck (1902), Hof and Frémy (1933), Hof (1935a) and Hof (1935b).

17 In the 1953 manuscript of *Geobiology* (p. 393-397) Baas Becking described the case of Lake Bumbunga.

5.2.5 Summary and conclusions

[Baas Becking left this section blank.]

5.3 Radiation

5.3.1 Introduction

The fundamental law of photochemistry (Grothius-Draper) states that light, in order to act, should be absorbed. This means that the living state should show absorption bands at the places of the spectrum where radiation is utilised. Another fundamental law of photochemistry is given by Einstein, where the energy necessary for a photochemical reaction may be expressed as $\Delta t = h\nu 1 - h\nu 2$ if the frequency $\nu 2$ be νc radial (fluorescence) ΔE be positive $\nu 1$ should be $>\nu 2$ from which follows that the wavelength of the fluorescent light should be larger than that of the absorbed light (Stokes' law).

5.3.2 Photosynthesis

[Baas Becking inserted Fig. 5.2.]

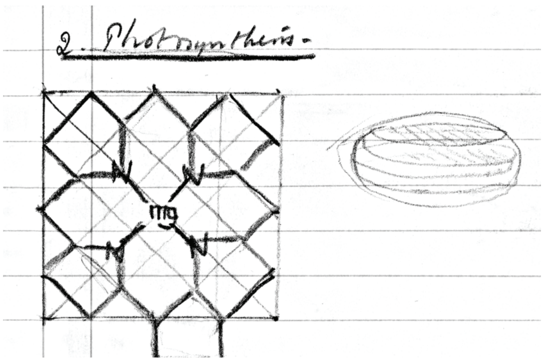


Figure 5.2 Rough sketch of the molecular structure of chlorophyll that shows the chlorin ring whose four nitrogen atoms surround a central magnesium atom.

Bluegreens, purples under quartz, under salt.[18]

5.3.3 Chromatic adaptation

[Baas Becking inserted Fig. 5.3, a small drawing of light spectra green and purple bacteria.]

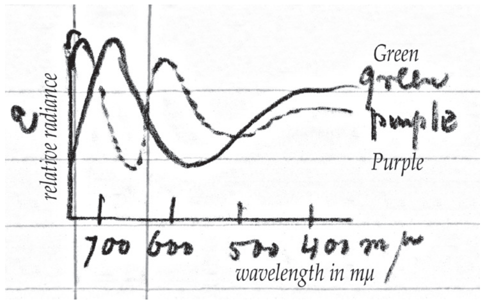


Figure 5.3 Light transmittance of green (*Euglena*) and purple (*Rhodospirillum*) cells (Baas Becking, 2016, Figure III.9).

5.3.4 Vision

Eye of *Gyrinus*.[19] Melanophore contraction.

[Baas Becking inserted a rough sketch of light spectrum of the eye of *Gyrinus* (Fig. 5.4).]

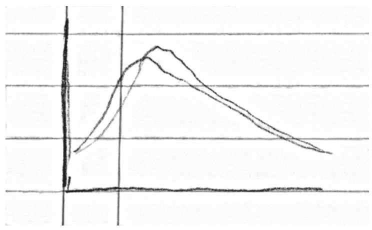


Figure 5.4 Rough sketch of light spectrum of the eye of Gyrinus (without legend).

5.3.5 Formative influences

Light and shadow lenses. Etiolation.[20] Other influences.

5.3.6 Photoperiodicity

[Baas Becking left this section blank.]

5.3.7 Germicide action[21]

[Baas Becking left this section blank.]

5.3.8 The ultraviolet

[Baas Becking left this section blank.]

5.3.9 Germitisation

[Baas Becking inserted a rough sketch Fig. 5.5.]

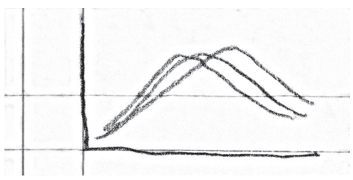


Figure 5.5 Rough sketch of light spectrum (without legend).

18 This is evidently a note from Baas Becking to remind him that this section needs to be expanded.

19 Reference to the whirligig beetle, *Gyrinus substriatus* or *Gyrinus natator. Xenogyrinus natans*, extinct species, well known in Dutch literature as 'Het Schrijverke (*Gyrinus natans*)' by Guido Gezelle. This species was first described in 1845 by Peter Bellinger. However, Gezelle referred to the before mentioned species *G. substriatus* or *G. natator.*

20 Etiolation is a process in flowering plants grown in partial or complete absence of light. It is characterised by long, weak stems; smaller leaves due to longer internodes; and a pale yellow colour (chlorosis). Elongation is controlled by auxines which are produced by the growing tip to maintain apical dominance. Auxin diffuses, and is transported, downwards from the tip, with effects including suppressing growth of lateral buds. Auxins are active in light; when they are active, they stimulate proton pumps in the cell wall which increases the acidity of the cell wall and activates expansine (an enzyme that breaks bonds in the cell wall structure) that weaken the cell wall and allow the cell to expand.

21 Baas Becking probably referred to Ultraviolet Germicidal Irradiation, a means of disinfection. The bacterial action of ultraviolet light was studied in the 20s and 30s of the last century.
See Reed (1974), *The History of Ultraviolet Germicidal Irradiation for Air Disinfection.*

5.3.10 Summary and conclusions

[Baas Becking inserted Fig. 5.6, light spectrum in relation to sensitivity of organisms.]

Text box 5.1 – Baas Becking notes made prior to writing the manuscript

Baerends (1943) shows how little change in the ocean water sufficient change composition fish fauna, tunny not <14 °C, *etc.*, sole *etc.*[22] Schenk (1917), Interlaken,[23] temperature of 200-300 °C in heating hay! (see Schwarz and Laupper, 1922).

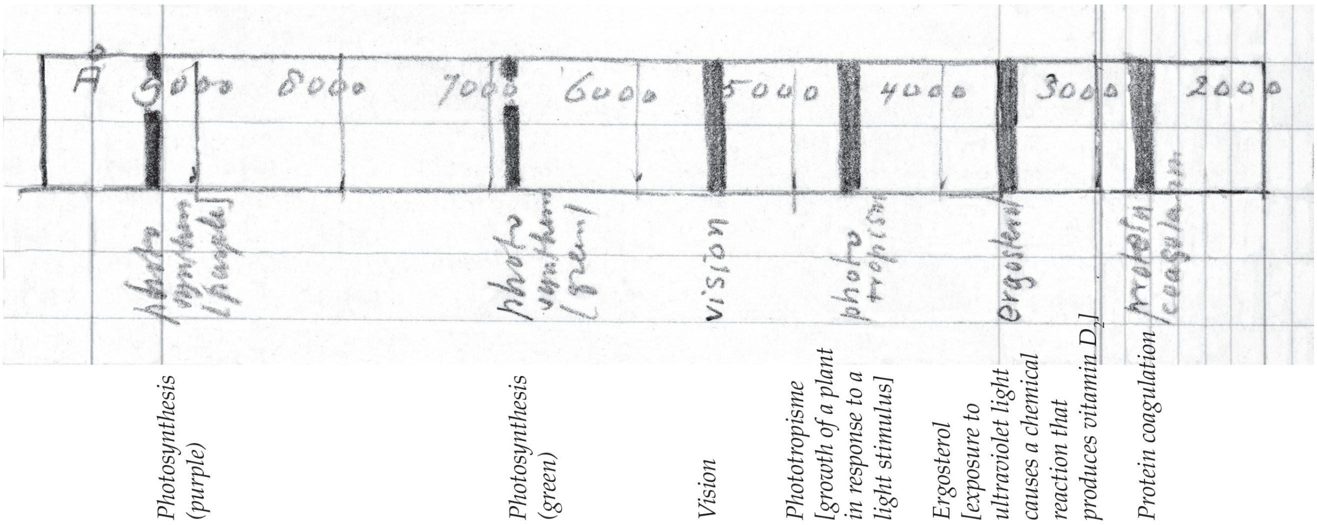


Figure 5.6 Light spectrum and sensitivity of various organisms or chemical compounds. Photosynthesis (purple), Photosynthesis (green), Vision, Phototropisme [growth of a plant in response to a light stimulus], Ergosterol [exposure to ultraviolet light causes a chemical reaction that produces vitamin D_2], Protein coagulation.

5.4 Temperature

5.4.1 Introduction

Temperature is nothing but the statistical average of the velocity of the molecules in a system. The absolute void has no temperature and interplanetary space has only temperature in so far as it can burst on material particles. Organisms are excited by, or put to sleep by temperature, not merely because they consist chiefly of water and the properties of water change so much with temperature, but because equilibria are upset, (sweetening of potatoes, work of B.D.J. Meeuwisse).[24] Only a long monograph would do justice to this subject matter. In this section we shall only select a few high spots and deal with those, of course rather superficially. But the argument should not be too long.

5.4.2 Influence of very low temperatures

A great many organisms, especially in spore form, are able to withstand extremely low temperatures (see Baas Becking, *Geobiologie,* 1934). Vital functions, however, should stop whenever the liquid phase disappears. D'Hérelle (oral communication) found an *Aspergillus* in a brine bath at -35 °C. Systematic study of the behaviour of organisms at very low temperatures seems not to have been carried out. Necrobiotic effects take place at -40 °C, while in deep freezing fruits it may be observed that the oxidase activity (Cu-containing proteid; Kubowitz)[25] the peroxidase activity (Fe-containing porphyrine proteid, Kylin)[26] and the katalase activity not only remain unimpaired, but continue, very slowly, at these improbable temperatures.[27] Also, amylase activity could be demonstrated. It has been suggested (Gortner,[28] Kruyt, Baas

22 'Baerends (1943)' not identified. Reference to Gerard Pieter Baerends (1916-1999) Dutch ethologist and fisheries biologist, Professor of Zoology at Groningen University. See for his relationship as a student in Leiden with Baas Becking: Baerends (1985).

23 Not identified.

24 Baas Becking referred to Bastiaan Jacob Dirk Meeuse (1916-1998). During his study in Leiden, Meeuse was inspired by Baas Becking. The reference is to his 1943 PhD thesis, *Oriënterende Onderzoekingen over de Vorming van Rietsuiker uit Zetmeel in Planten bij Lage Temperatuur* (Delft, G. van Iterson, supervisor). From 1952 until 1986, Meeuse was Professor of Botany at the University of Washington, Seattle.

25 Kubowitz (1938).

26 Reference to the Russian-British entomologist David Keilin (1887-1963), most known for his research and re-discovery of cytochrome in the 1920s: Keilin (1925). See also Slater (2003).

27 'Proteid' is an obsolete word for a protein molecule.

28 Reference to Gortner (1930). In the 1953 version of *Geobiology* Baas Becking referred to Gortner:

> The problem of the state of water in colloidal systems was, in the meanwhile, approached from another angle. Gortner approached the problem from a colloid chemical angle, that more advance was made. According to Gortner, water may exist, in a colloid (like protoplasm) in various states: it may exist as free molecules, as molecules bound osmotically or as hydrates and further it may occur as swelling water, tightly bound to hydrophilic, colloidal particles.

Becking) that part of the water remains in the non-frozen condition at very low temperatures (far below the freezing point). To call this water "bound water" makes more claim for our knowledge of, and insight into the effect, than we desire (Baas Becking, 1942b).[29]

5.4.3 Influence of very high temperatures

[Baas Becking inserted Fig. 5.7, the link between intensity of a biological phenomenon, time and temperature.]

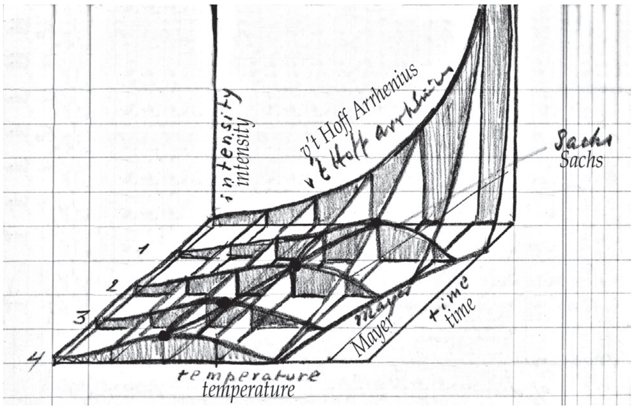


Figure 5.7 Link between intensity of a biological phenomenon, time and temperature from (Baas Becking, 1934, Figure IV.4).

5.4.4 Temperature table

[Baas Becking left this section blank.]

5.4.5 Temperature and humidity

[Baas Becking inserted Figs. 5.8a and 5.8b (both schemes from Shelford, 1929).][30]

Dry interior U.S. (1900-1912). 71,000 deaths (Huntington).

5.4.6 Summary and conclusions

[Baas Becking left this section blank.]

> ***Text box 5.2 – Baas Becking notes made prior to writing the manuscript***
> *Protozoa* (Kudo) including authors. *Euglena* spp. pH 3.0-9.9, *Paramoecium* sp. pH 7.0-8.5, *Paramoecium caudatum* Ph 5.3-8.2, *Stylonychia pustulata* pH 6.0-8.0, *Colpidium* sp. pH 6.0-8.5, *Colpoda cucullus* pH 5.5-9.5.

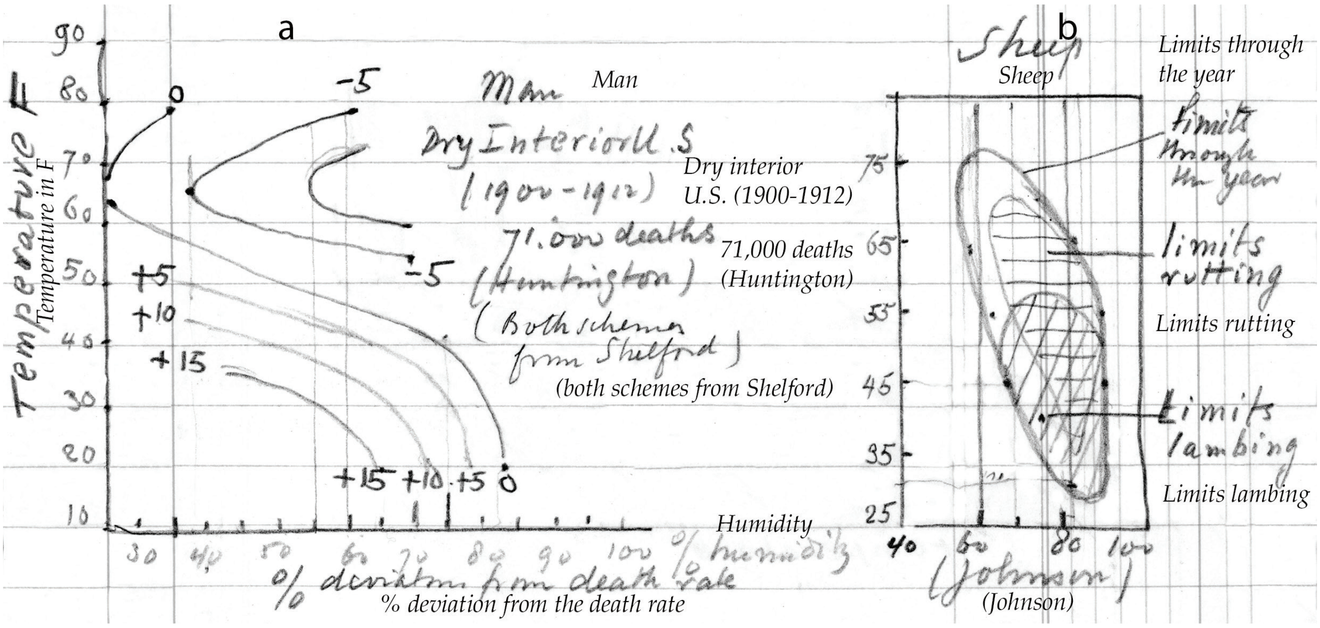


Figure 5.8 The relation between temperature and humidity and % death rate **(a)** for man and **(b)** for sheep (from Shelford, 1929 and Johnson, 1924). **(a)** Man: Y axis Temperature in F; X axis: from 30 – 100% humidity. Lines between the axis: % deviation from the death rate. **(b)** Sheep: Limits through the year; Limits rutting; Limits lambing.

29 Reference to Baas Becking (1942b). See also Section 3.5.21, *Free and bound water.*
The section about deep freezing fruit was probably also based on the work of Baas Becking and Henri Derx for Unilever (1942-1944). See for reference to the classified reports *Bibliography L.G.M. Baas Becking and of Pupils and Co-workers* 1948. Document AAS Basser Library 043 nr. 161. In the 1953 version of *Geobiology* Baas Becking referred to his research in the Unilever laboratory (see Section 3, note 72).

30 Apparently Baas Becking took the two diagrams from Shelford (1929). The left hand graphs were taken from the work of Ellsworth Huntington (1876-1947), an American geographer known for his studies on environmental determinism. The right hand diagram was taken from Johnson (1924).

5.5 Acids and Bases

5.5.1 Introduction

Natural milieu contains only a few acids and bases which exert a dictating influence, although, actually the number of acids and bases in natural environment is legion.

Inorganic acids

1. H_2CO_3, 2. H_2S, 3. HNO_3, 4. H_2SO_4, 5. H_3PO_4, 6. HCl.

Inorganic bases

1. Na_2SiO_3, 2. $Al(OH)_3$, 3. $NaHCO_3$, 4. Na_2CO_3, 5. Na_2S, 6. NH_3.

Of the organic substances we shall deal only with five

1. Oxalic acid, 2. Humic acid, 3. Butyric acid, 4. Lactic acid, 5. Acetic acid.

HCO_3 is, of course, the 'photosynthetic acid.'

5.5.2 pH and pH range of the milieu

Silica may be toxic to certain organisms. Apart from human siliciosis. Dr. P. Schure found glan, mica and even quartz toxic to swarmers and myxamoeba of *Reticularia lycoperdon*.[31]

5.5.3 Oxalic acid

Formation [of oxalic acid] obscure. Breakdown by a curious enzyme (Fig. 5.9). Zaleski isolated the enzyme from wheat. Kruyt says plentiful in mosses. Bassalik bacteria.[32] Franke and Hasse more recent study. Niekerk (unpublished).[33]

$$(COOH)_2 = 2CO + H_2O_2,$$

and with access of water

$$2CO + 2H_2O = 2\,HCOOH$$

$$2HCOOH = 4\,H + 2CO_2,$$

and with access of oxygen

$$4H + O_2 = 2\,H_2O.$$

Table 5.1 Relationship between pH and natural milieu.

pH	Natural milieu	solubility		organisms	cause
12				Bacteria in soap lyes (McBain) [34]	Na_2CO_3
11		$Mg(OH)_2$ ↓		Ephydia, *Dunaliella*	
10	Searles' Lake			Nematodes, Amoebae	$NaHCO_3$
9	Condemer Reservoir	9.2 $CaCO_3$ ↓			$CaCO_3$, $Ca(OH)_3$
8	Ocean				HCO_3^-
7	Blood	↓ SiO_2			
6		↓ Fe^{2+}			
5	Rain	↓ Fe^{3+}	Ca oxalate ↓		H_2CO_3, HCO_3^-
4		↓ Al^{3+}			
3	Spagnum bog	All biological metals in solution		*Desmids*	HCl, H_2SO_4
2	Volcanic lake			*Amoeba*	H_2SO_4, HCl
1					
0	Oxidised sulphide clay			*Thiobacillus thiooxidans*	H_2SO_4
-1					

31 Dr. P.S.J. Schure, Baas Becking was her PhD supervisor in Leiden. The reference is to Schure (1935a and 1935b), Table 14, *Survival of the Swarm Cells in Drops with Few Spores on Different Surfaces.*
See also Section 7.7.4.

32 Kazimierz Bassalik (1879-1960), Polish microbiologist, professor Warsaw University. Reference to Bassalik (1913), his '*Bacillus extorquens* n. sp' has the present name *Methylobacterium extorquens.* See also Bassalik-Chabielska (1980).

33 In the 1953 manuscript of *Geobiology* Baas Becking (p. 657) referred to C.J. Niekerk-Blom's 1946 publication:

> The 'lonely' compound at reduction level (1), oxalic acid, remains a biological enigma. It is of very wide occurrence in the plant kingdom, and often most abundant, but its mode of origin is still obscure. It is oxidised both by bacteria and by higher plants, sometimes with the formation of hydrogen peroxide.

Mrs Niekerk referred to Zaleski and Reinhard (1911), who discovered the degradation of oxalate by plant material in wheat. She also referred to Bassalik (1913) and to Franke and Hasse (1937).
See for more recent research: Davoine *et al.* (2001), who investigated changes in the activity of the extracellular enzyme oxalate oxidase and the concentrations of oxalate and H_2O_2 during the ageing of leaf sheaths of ryegrass. The accumulation of H_2O_2 during ageing coincides with the increase of both oxalate level and oxalate oxidase activity. Overall, results suggest that in ryegrass that synthesises both Ca oxalate and oxalate oxidase, the production of H_2O_2 and Ca^{2+} during ageing of stubble might be involved in the constitutive defenses against pathogens, thus allowing the phloem mobilisation of nutrient reserves from the leaf sheaths towards elongating leaf bases of ryegrass.

34 Reference to James William McBain (1882-1953). Canadian/American chemist. Professor of Chemistry, University of Stanford (1926-1947). He devoted many years to the elucidation of the nature and structure of soap-rich aqueous systems.

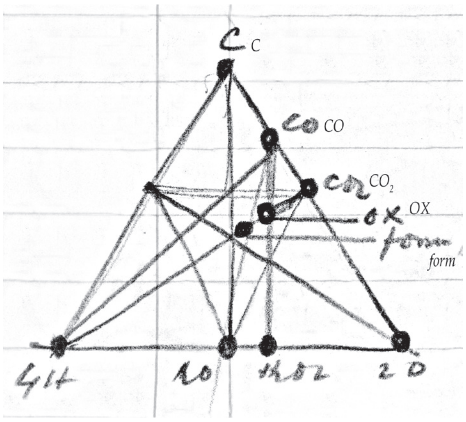


Figure 5.9 Equilateral triangular plot with compounds C – 4H – 2O showing location of oxalate on line C – H_2O (reduction level 4).

It is very remarkable that H_2O_2 should be formed here, while in mosses there is catalase present. The enzyme is highly thermostable and works in highly acid media. *Bacteria extorquence* in the gut of earthworms (Bassalik, 1913) is also able to attack $Ca(COO)_2$, one of the stable 'organic compounds' (only soluble in pH < 2. It is therefore probably the only organic acid that enters in appreciable quantities in the carbon cycle (leafy humus)

May be formed from CO and H_2O_2? Better a scheme of Chibnall (1939).

5.5.4 Occurrence of mineral milieu as solute as function of milieu

[Baas Becking left this section blank.]

5.5.5 Summary and conclusions

[Baas Becking left this section blank.]

5.6 Osmotic Milieu

5.6.1 Introduction

After the classical work of de Vries (1883-1884) and Hamburger (1884), the osmotic value of the milieu, whether hypotonic or hypertonic in relation to the inner environment, has been recognised as a factor of prime importance.[35] Marine animals brought into freshwater take up an inordinate amount of water, which they have to recrete. This fact, originally considered as a purely osmotic phenomenon, requires other concepts for its final understanding (see Section 4.2.5.a). Also, the fact that organisms may exist in saturated salt solutions, and still are able to take up water, cannot be accounted for by osmotic theory. The phenomenon of swelling and of antagonism have to be taken into account to create a harmonious theory of water intake and of water recretion. It should never be forgotten that the classical osmotic theory only refers to water movement and that all other phenomena require theories on intrability and on permeability. It may be stated in advance that the pressure of at least two semipermeable membranes in a plant cell has been proved.[36]

5.6.2 Osmotic pressure and osmotic phenomena

Van 't Hoff, using the data of W. Pfeffer (1877) established the fact that the osmotic pressure, expended [exerted] by a sucrose solution against a semipermeable membrane (Cu, ferrocyanide), followed the gas laws (Fig. 5.10).[37] PV = RT or rather, *per* unit volume P = cT, in which c is concentration. A one molar solution of cane sugar may generate a pressure of 22.4 atmospheres. De Vries found, by means of his "plasmolytic method" that electrolytes acted as if they were much more concentrated. The "isotonic coefficient", a multiplication factor to satisfy theory, proved to be, for NaCl almost 2, for $Ca(NO_3)_2$ almost 3 *etc*. Arrhenius (1887) from these data and other cryoscopic and conductivity measurements, derived his ionic theory. The ions behaving as separate particles in the solution. A saturated NaCl solution, practically 100 % dissociated and approx. 5.25 molar, should yield an osmotic pressure of 10.5 × 22.4 = 235 atmospheres.

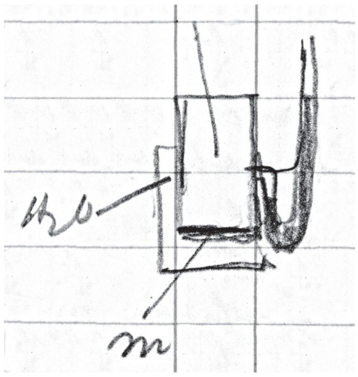


Figure 5.10 Rough sketch of the van 't Hoff experiment. The vessel with sucrose solution is attached to a manometer and separated from the vessel with water by membrane m.

5.6.3 Simulacra vitae

(Dubois, Herrera, Traube).[38] The copper ferrocyanide membrane, but particularly the metal-silicate membrane is somewhat plastic a crystal of nickel sulphate in a solution of sodium silicate will form a semipermeable membrane of nickel silicate, surrounding the crystal. The high concentration of

35 Erik Zevenhuizen (2008), in his biography of Hugo de Vries, discussed the work of Hugo de Vries, H.J. Hamburger and H. van 't Hoff on osmosis in cells of plants and animals in the late 1870s and 1880s (p. 172-180). See his notes 191 and 192 on p. 559-560.

36 For 'recretion' and 'intrability' see Section 4.2.5.a.

37 See Zevenhuizen (2008), p. 172-175, 559 (notes 187-190). J.H. van 't Hoff (1884) used the data from Pfeffer (1877) for his *Etudes de dynamique chimique* in which he published his results of osmotic studies in solutions.

38 In the lemna 'Protoplasma' in the *Encyclopaedisch Handboek van het Modern Denken* (1931/1942), Baas Becking remarked:

> Speaking of "living matter" is termed "logical nonsense" by modern Russian researchers; And in my opinion rightly so. Driven by the desire to make life itself one day in the test tube and specially to put the monadological and monistic crown on the great unifying work of the last century, many have allowed themselves to be seduced into premature conception. The whole interlude of "the living matter" is superfluous in the development of science and would never have taken place if the word protoplasm had been left alone without linking it to the then development of chemistry. As an afterglow of this school one still finds people who, in the imitations of life phenomena, as one shows them in the test tube (the so called simulacrum vitae) see indications of how one will have to prepare the "living matter" in the not too distant future.

Raphael Dubois (1849-1929), Professor of Physiology at Lyon, produced particles that were supposedly identical to bacterial cells by adding barium or radium chloride to sterilised fish broth. The reference is to Dubois (1919).

Alfonso Luis Herrera (1868-1942), Mexican physiologist, was convinced that life could be created in the laboratory. He proposed an autotrophic theory he called plasmogeny. See Cleaves *et al.* (2014).

Moritz Traube (1826-1894), German physiologist. In 1864 Traube was the first to produce semipermeable membranes. See Traube (1866).

Ni^{2+} and SO_4^{2-} ions within the membrane will cause a flow of liquid towards the crystal. The membrane is stretched, bursts and new membranes are formed. In this way curious plant-shaped structures may be formed. However, it is as futile to compare these structures with vital growths, as it is to account for the annual rings in the trees as a Liesegang phenomenon.[39] A plant cell will take in water till the turgor equalises the tension of the cell wall. Growth proceeds when, by means of growth hormone, the plasticity of this cell wall is increased, and the turgor pressure may again become active in stretching the plastic wall till it reacts again to the renewed tension.

5.6.4 The rhythm of the pulsatory vacuole

Several protozoa, myxomycetes and conjugate algae possess a pulsating vacuole which recretes water at a certain rhythm (Fig. 5.11 after C.V. Taylor (1923), on *Euplotes*).[40] In a freshwater milieu the rhythm is frequent, transference in a milieu of high osmotic value causes the frequency to decrease (data from Pelseneer, and Yves Delage).[41]

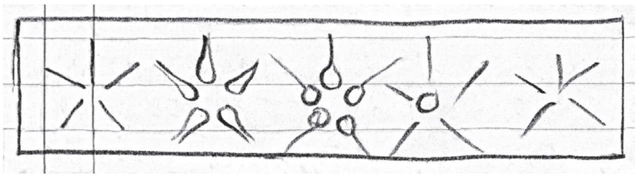


Figure 5.11 Contractile vacuoles in *Euplotes* according to Taylor (1923).

5.6.5 The secretion and intake of water

[Baas Becking left this section blank.]

5.6.6 The problem of salt organisms

[Baas Becking left this section blank.]

5.6.7 Theory of salt organisms

[Baas Becking left this section blank.]

5.6.8 Theory of water

[Baas Becking left this section blank.]

5.6.9 Osmophilic organisms

Published in the *Arch. f. Mikro*[*biologie*].

5.6.10 The actions of distilled water

Noel Patten, *Nereis*,[42] LBB *Evadne*.[43]

5.6.11 Swelling and osmosis

M. Fischer.[44]

5.6.12 Summary and conclusions

Water intake cannot proceed by osmotic forces only. The swelling of biocolloids has to be taken into account as well.

5.7 Antagonism

5.7.1 Introduction

At the outset it is well to point out, that the word "antagonism" is used by pathologists in a different sense, *viz.*, the inimical action of certain microbes towards one another. The word however, is pre-empted by physiologists to indicate originally the phenomenon that 2 substances, A and B, in themselves toxic, may appear to exert a beneficial influence upon an organism when combined (Fig. 5.12). Now pharmacologically the effect may be, moreover *additive*, as the two toxic agents may, in combination, enhance each other's effect. In the latter case we meet with *sensitisation*. There are many in analogues in physical chemistry. Boiling point, melting point, viscosity, *etc.*, if a brisant mixture may be either additive or non-additive. This is particularly striking in the case of alloys. Physiological antagonism is important to geobiology as the oecomena of organisms in natural mineral milieu depend, for a large part upon the antagonistic action of the combined mineral components which may, in themselves, be highly toxic. In the milieu interne we meet, moreover, with body fluids which show similar properties. It will be seen that antagonistic rather than osmotic effects dictate the boundaries of the milieu externe for a great many organisms. Although the study of the concept enjoyed its highlight in the school of Jacques Loeb, a renewal of interest would be very expedient, as the great number of most striking and suggestive observations have been made, which still await a basic, comprehensive, theory to account for them.

39 Liesegang rings, a phenomenon seen in many, if not most, chemical systems undergoing a precipitation reaction under certain conditions of concentration and in the absence of convection. Rings are formed when weakly soluble salts are produced from reaction of two soluble substances, one of which is dissolved in a gel medium

40 The reference is to Charles Vincent Taylor (1885-1946), an American biologist. His doctoral dissertation, done under the supervision of the parasitologist Professor Charles A. Kofoid, was entitled *Demonstration of the Function of the Neuromotor Apparatus in Euplotes by the Method of Microdissection*. Taylor was active at the University of California and the Hopkins Marine Station of Stanford University in the 1920s when Baas Becking was working at Stanford and the Marine Station. In 1933 Taylor was made Herzstein Professor of Biology, the chair that was occupied by Baas Becking until 1931.
Baas Becking referred to Taylor (1923), *The Contractile Vacuole in Euplotes*. Contractile vacuoles are subcellular organelles which are defined by their behaviour of filling slowly with fluid, and periodically expelling their contents from the cell. It is a membrane bound osmoregulatory organelle of freshwater and soil amoebae and protozoa which segregates excess cytosolic water, acquired osmotically, and expel it to the cell exterior, so that the cytosolic osmolarity is kept constant under a given osmotic condition.
See also Danforth (1947).

41 Jean Paul Louis Pelseneer (1863-1945), Belgian malacologist, morphologist, ethologist and phylogenist. Baas Becking probably referred to Pelseneer (1905). In this study Pelseneer discussed the osmotic changes in fishes migrating from a saline to freshwater environment.
Yves Delage (1854-1920), French zoologist, since 1901 director Station Biologique de Roscoff. Baas Becking probably referred to Delage (1895).

42 The reference to the polychaete worm *Nereis* and to the American zoologist and palaeontologist William Patten (1861-1932) and his research on the vision of *Arca noae* and *Nereis*. See Patten (1886).

43 *Evadne* refers to marine crustacea that have the ability to stay alive for a long period of time in distilled water. See Baas Becking in *Geobiologie* (1934, English edition, p. 50). See also Section 5.2.3.

44 Reference to H.W. Fischer (1910), Gefrieren und Erfrieren. See also H.W. Fischer (1911), Das Wasser im plasma.

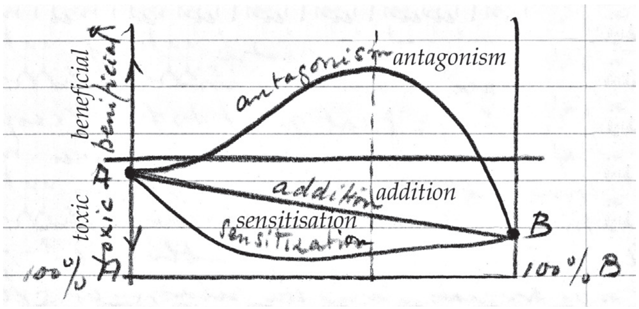


Figure 5.12 Possible toxic or beneficial effects on organisms, antagonistic, additive and sensitive, of substances A and B when combined.

5.7.2 Historical: Ringer

Sydney Ringer, in 1881, succeeded in keeping a frog's heart beating by perfusion with an extract of dried ox blood.[45] Later he used a weak solution of common salt. Repeating the experiment with a solution of NaCl in distilled water, the heart stopped beating. It is Ringer's great merit to have recognised the nature of the phenomenon: NaCl in itself was toxic, but it became detoxified by the calcium in the London tapwater. Ringer also recognised the two types of solution needed; 0.9 % for warm blooded, 0.7 % for cold blooded animals, and the relation of the Na:Ca, in atmos 40:1.

5.7.3 Historical: Loeb, Osterhout[46]

[Baas Becking left this section blank.]

5.7.4 Hypothesis of seawater: McClendon[47]

The blood of the mammal is an archaic seawater, taken from the primordial ocean when in evolution, the aquatic animal became a land animal. Now it is true that the freezing point depression of the blood of cartilaginous fishes (rays, sharks) varies but little from that of the surrounding seawater, unfortunately that serum is no seawater as the osmotic regulation is performed by means of urea.

[Fig. 5.13 see also Figure IX.6 in *Geobiology,* 2016.]

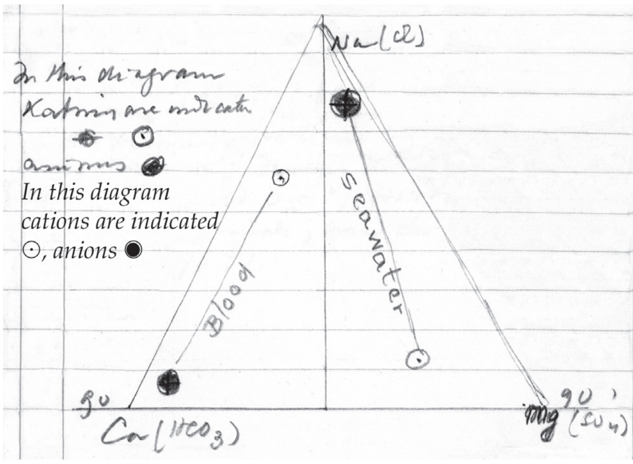


Figure 5.13 Upper part of equilateral triangular plot with compounds NaCl – $Ca(HCO_3)$ – $Mg(SO_4)$ in which the equivalent ratio's of anion + and cation ⊙ of human blood and seawater are depicted (Baas Becking, 2016, Figure IX).

Seawater [corrected in purple pen by "blood"] has proportionally much more Mg and HCO_3 than seawater. It looks like a seawater which has exchanged bases with soil (Rockanje Lake, Island of Voorne, oil waters of Tjepin and other subsoil wells, central Java).[48]

45 Perfusion is the passage of fluid through the circulatory system or lymphatic system to an organ or tissue, usually referring to the delivery of blood to a capillary bed in tissue. Baas Becking discussed the Ringer experiments in *Geobiologie* (1934, p. 100-101 in English edition, 2016).

46 Reference to Jacques Loeb (1859-1924), German born American physiologist and biologist. Since 1910 he remained at the Rockefeller Institute for Medical Research in New York. He spent his summers at the Marine Biological Laboratory in Woods Hole. March 4, 1922 Baas Becking wrote to F.A.F.C. Went that he visited Loeb and Loeb's former assistant, the physiologist and Harvard Professor W.J.V. Osterhout (1871-1964) on his journey from Holland to Palo Alto. Loeb and Osterhout were editors of the *Journal of General Physiology*. They published two papers by Baas Becking in 1920 and 1921 [Hampton and Baas Becking (1920) and Baas Becking (1921c)].
Letter L.G.M. Baas Becking to F.A.F.C. Went Stanford University Palo Alto March 4, 1922. Correspondence F.A.F.C. Went Library Boerhaave Museum Leiden.
In his 1951 lecture *Forgotten Biology*, Baas Becking (1951b) referred to Loeb as:

> My respected teacher, Jacques Loeb, saw a future for biology in which the certainty of the results would equal those in chemistry and physics. However, the principle of uncertainty has entered in both chemistry and physics and, as living beings represent statistical populations of a much lesser magnitude than those met with in the molecular the atomic or the electronic state. The individual freedom of the variant always leaves its hallmark upon the results. We are striving towards the impossible if we set our course solely by the lights of our neighbouring sciences. Apart from the two attitudes towards biology mentioned above, there are recurrent raves of vitalism and of mechanistic thinking, which cloud the picture.

In 1927 in his course *General Physiology of the Cell* at Utrecht University, Baas Becking (1927-1928) referred to Loeb:

> Physical chemistry has been claimed by many to be the most powerful tool for the physiologist. Sinclair Lewis in his "Arrowsmith" made Professor Gottlieb (obviously Jacques Loeb) say:
> "*Organic chemistry! Puzzle chemistry! Stink chemistry! Dungstore chemistry! Physical chemistry is power, it is exactness, it is life. But organic chemistry – that is a trade for pot washers.*"

47 Baas Becking discussed McClendon in Chapter IX, *Geobiologie* (1934) and copied a figure from his publication, see English edition *Geobiologie* (2016, p. 96-97). Jesse Francis McClendon (1880-1976), an American chemist zoologist and physiologist, known for the first pH measurement of human stomach *in situ*. The reference is to McClendon (1916).
The reference to McClendon in the 1944 manuscript of *Geobiology* is probably a mistake for Macallum. In his Inaugural Address as extraordinary professor at Utrecht University, October 3, 1927, Baas Becking referred to Archibald Byron Macallum (1858-1934), who published in 1908, *Cellular Osmosis and Heredity*'.

48 In the 1953 manuscript of *Geobiology* Baas Becking discussed six salt-water mineral wells at Sapta Tirta near Pablengan, Java (p. 378-379):

> From the analyses of ter Haar it appears that the salt waters of this region represent a distinct type, resembling seawater, but with less sulphate. The high iodide and ammonia (see analysis Delok) [a salt water well near the town of Tjopu near the river Gagakan] show a large biogenic element in the origin of these waters. Rather close to this type of water is a brackish lake near Rockanje on the island of Voorne, Holland, known for its lime deposits.
> The high calcium carbonate content of the water mentioned and the comparatively low pH (ranging from 5.9 – 7.2, average 6.5) together with its often very high content of H_2S and suspended lime may be conceived as seawater in contact with groundwater and calcium carbonate with a large amount of sulphate reduction. [Baas Becking inserted: To account for the disappearance of the anion]. The disappearance of the magnesium is not accounted for, unless a permutate action (base exchange) with soil particles might be the cause (Takir Ghiol [Lake Techirghiol Rumania, known for its sapropel: dark coloured sediments rich in organic matter]).

Baas Becking probably referred to Ir. Carel ter Haar, a Dutch geologist who discovered in 1931 along the Solo River on Java fossils of *Homo erectus*, nowadays considered the last *Homo erectus*, which lived until 200,000 years ago.

If this serum has anything to do with a natural water it is certainly not seawater. Now it may be claimed that "while the ocean got 'saltier and saltier' the ionic points travelled in the triangle" as indicated in Figure 5.14 for a trip down river towards the ocean. This is an unsafe assumption, as the NaCl in the ocean cannot be accumulated there by weathering alone (see Sections 2.3.1 and 2.4.6). We do not know how the ocean came to be. Probably volcanic action extends into the game at certain instances. And taking the concentration of the blood in NaCl 0.62 %, the triple [?] point of such a natural water would still be situated right near that of seawater (see Section 5.7.4 and Fig. 5.14 for freshening of the Zuyderzee). The hypothesis therefore is clever, but exceedingly improbable.[49]

5.7.5 Classification of phenomena

Jacques Loeb claimed that, seawater was, as far as ionic balance was concerned, "an ideal abode." Osterhout went so far as to culture wheat in diluted seawater. What probably happens in seawater is that it behaves like an "antagonistic buffer", dilution and concentration over a small sample did not influence the ionic balance. But any other claim as to the superiority of seawater no experiment has, as far as the author knows, substantiated.[50]

5.7.6 Natural waters again

The composition of seawater is dictated by organisms (Fig. 5.14 and Table 5.2). [The figure shows the changes in percentual composition of average river water R to oceanic water, for 8 components.]

- Silica disappears, bicarbonate almost disappeared
- Sulphate decreases
- Calcium decreases
- C = Caspian Sea (diluted with Wolga and Ural water)

See also Figure 6.3 and Section 6.4.2.c.

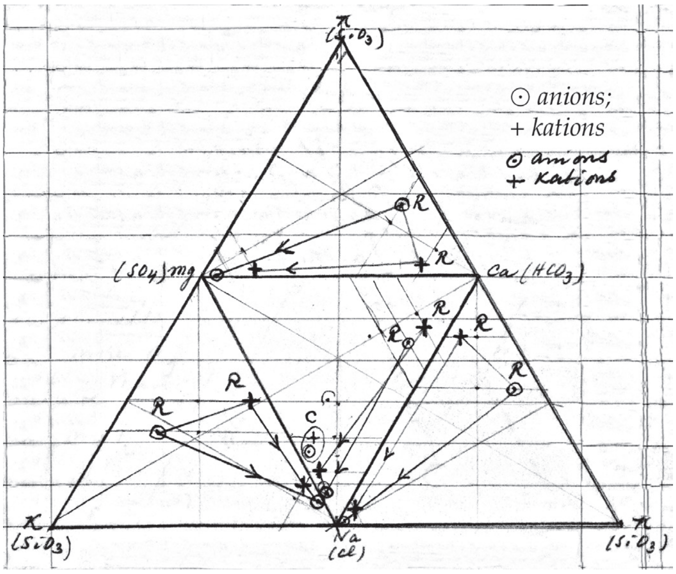


Figure 5.14 Combined equilateral triangular plot with eight equivalent compounds of river and seawater, showing the changes in percentage composition of average river water (R) to oceanic waters: ⊙ anions; + cations. Data from Clarke (1916, p. 115).

M equivalents (proportional)		
	River	Ocean
HCO_3	586	3
SO_4	253	160
Cl	161	1580
SiO_3	324	0
Na	252	1330
K	55	29
Ca	1020	59
Mg	284	310

49 The relation between internal fluids of organisms and seawater was a topic of fascination for Baas Becking. In the 1934 *Geobiologie*, he discussed the physiological and evolutionary significance of this (p. 100-101; Eng. version). In the 1953 manuscript of *Geobiology* (p. 487-488) Baas Becking wrote:

> Macallum, in 1908, considered the blood serum of higher animals as an ancestral seawater trapped, as it were in the milieu interne. Henderson (1913) adhered to this belief. He states (l.c.p. 187) "not only do the body fluids of the lower forms of marine life correspond with seawater in their composition, but there are at least strong indications that the fluids of the highest animals are really descended from seawater." This statement has been challenged by many (Baas Becking, 1934; Hutchinson, 1948) but it should receive the attention that it deserves as a bold and inspiring. [….] If Macallum's hypothesis were true, and organisms arose, in the course of evolution, from their ancestral sea, the first emergent creatures would have left an ocean of a very curious composition, the salts consisting chiefly of NaCl, with a rather high calcium and carbonate content, and much lower in magnesium and, especially in sulphate, then the present ocean. We have to account, moreover, for an ever increasing concentration of potassium. It would run counter to the hypothesis of a constant plutonic addition of chloride, but rather strengthen the theory that, when water became liquid, there was already much halite available on the earth. [Baas Becking inserted: which salt was dissolved first.] Dr. G.W. Leeper called my attention to the fact that NaCl melts at 800 °C and could, therefore, have occupied basins on the earth's surface when the first rocks solidified. It must have been, (if we take the consequences of Macallum's theory) a chloro-carbonate to a chloride water of approximately 0.7-0.9 % NaCl, faintly alkaline and in composition not unlike Natron Lake, near Thebes, Egypt (total solids 0.441 %). Much of the charm of this speculation, however, disappears when we take into account the osmo-regulative powers, especially in the higher vertebrates. A similar argument as given above might be applied to the salt content of the blood, in order to arrive at the concentration of an archaic seawater.
>
> Macallum (1926) noted that, although similarities between seawater and organismal fluids, such as blood and lymph, indicate that the first animals emerged in the sea, the inorganic composition of the cell cytosol dramatically differs from that of modern seawater. Macallum insightfully pointed out that "the cell […] has endowments transmitted from a past as remote as the origin of life on earth."

Baas Becking further referred to Geoffrey Winthrop Leeper (1903-1986), from 1946 till 1962 Associate Professor in Agricultural Chemistry at the University of Melbourne. In 1962 professor. Leeper edited *The Evolution of Living Organisms* (1962), with papers of the symposium to mark the centenary of Darwin's *Origin of Species*, held in Melbourne, December 1959, which contained Baas Becking's paper *On the Origin of Life*.

50 Baas Becking referred to Jacques Loeb's experiments on the role of salt for preservation of life. Loeb (1911), Loeb (1914).
In the 1953 version of *Geobiology* Baas Becking referred in Section *Antagonism* on p. 483 to Loeb and Osterhout:

> Especially through the work of Loeb and Osterhout a great many cases of this antagonism, both in animals and in plant have come to light. Mixtures of salts which antagonise completely the individual toxic actions are called "balanced solutions." Ringers solution, widely used in physiological practice, is such a balanced mixture. In general, the antagonistic effect is most pronounced if the valence of the component ions is different. It has been found that NaCl and $CaCl_2$ solutions, both slightly hypotonic for plant cells cause plasmolysis when mixed in a proportion 10 NaCl : 1 $CaCl_2$. It appeared that the solutions, containing the single salts, increased the permeability of the protoplast while, in combination the permeability was decreased, so that plasmolysis could take place. The permeability of the protoplast increases by application of cations in the following sequence:
> Ca < Ba < Mg < Li < Na < K
> […]
> Loeb has already shown that seawater could be diluted over a rather large range, without a change in physiological effect on various organisms, if the ionic proportions remained the same. The influence of ionic proportions may be studied to great advantage in euryhaline organisms, as here the organisms seem, in a way, independent of its osmotic milieu. […]
> Loeb has sung the praise of seawater as a balanced solution. Blood is certainly a balanced solution. It seemed inevitable that these two should be brought together. In 1902 G. Bunge (cited by Lotka, 1924, p. 203) expressed the opinion that be salt present in vertebrates, especially in the cartilage and in the serum, might be interpreted on an evolutionary basis.

1) The biologically active ions have all decreased on their journey

2) Na and Cl, biologically much less active, have accumulated

a) HCO_3 ion. Decrease due to photosynthetic active lime precipitation and oversaturation.

b) SiO_3. Probably entirely removed by organic agencies.

c) See HCO_3.

d) SO_4. Sulphate reduction!

e) K decrease still more.

According to Clarke (1916) very active, p. 146, "the biochemistry of the ocean is curiously complex, and its processes are conducted on an enormous scale." 300 million tons of sulphate being precipitated (reduced!). Surface earth ≏ 5.12×10^{18} cm^2. Complete reduction 96 g SO_4 yields 64 g oxygen or 200×10^6 ton. This would make no material difference in O consumption (see Section 6.4.3). Also see Figure 3.24, where more material has been brought together.

5.7.7 *Artemia*

[Baas Becking inserted Figs. 5.15 and 5.16.]

Literature

Baas Becking and Boone (1929) [= 1931].[51]

Baas Becking and Jacobi (1931) [= 1933].[52]

Baas Becking, Karstens and Kanner (1934) [= 1936].[53]

Booij and Bungenberg de Jong (1934) [= Bungenberg de Jong, Booij and Wakkie (1936)].

[The triangular diagrams are useful to illustrate boundaries of ionic milieu. Here the ionic antagonism plays a role, the cations being the most active in this respect. If total normality of the chloride constant (= 1 in the Fig. 5.15) the shaded area approximately represents the area in which eggs of *Artemia salina*, the brine hatch. This area is different for various normalities.

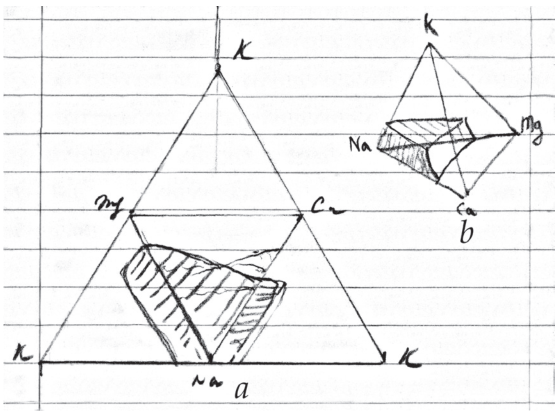


Figure 5.15 **(a)** Combined equilateral triangular plots with four equivalent compounds (cations K, Mg, Ca and Na) in a solution for hatching of *Artemia salina*. **(b)** The same data were used in the 3 D representation. From Baas Becking (2016, Figure X.19).

If concentration is used as a vertical axis we obtain a triangular prism, the cross sections of which are equilateral triangles, each corresponding to a certain normality (Fig. 5.16). For the hatching of the brine-shrimp eggs, between normality 0-4 we obtain the following figure, the solid, shaped like a part of an orange corresponding to the salt combinations in which hatching of the eggs is possible. It has been shown by Bungenberg de Jong and his coworkers that suspensions of lecitine assume a negative charge in certain three chloride combinations, while in other combinations the charge is positive, the 'negative' area coinciding, more or less, at 1 normal, with the area in which the crustacean eggs germinate.][54]

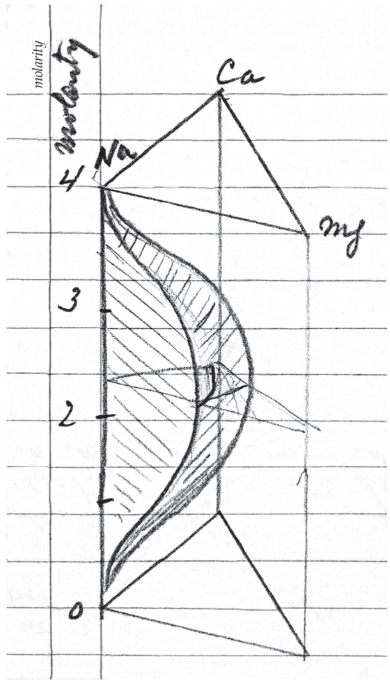


Figure 5.16 3 D equilateral triangular plot with Na -Ca -Mg cation equivalent compounds in a solution for hatching *Artemia salina* eggs at normalities from 0 to 4.

5.7.8 Oöspora and other microbes

[Baas Becking inserted Fig. 5.17. in which he indicated the potential environment for three chlorides for the fungus Oöspora. See also Figure X.18 in *Geobiologie* edition (2016). See also Figs. 5.18, 5.19b and 5.20.]

T. Hof, PhD Dissertation , Leiden (1935).[55]

Curling of liana[?].

51 Reference to Boone and Baas Becking (1931).

52 Reference to Jacobi and Baas Becking (1933).

53 Reference to Baas Becking, Karstens and Kanner (1936).

54 The explanation was taken from paragraph "ionic antagonism" in the unpublished essay *Seawater as a Chemical Milieu* (Baas Becking, 1945-1946). Oren (2011, p. 21-22) discussed Baas Becking's experiments on the limits of salt concentrations and other environmental conditions with special emphasis on the antagonistic effects of different ions.

55 See for the 1935 dissertation of T. Hof (Hof, 1935a) also Section 5.2.4.

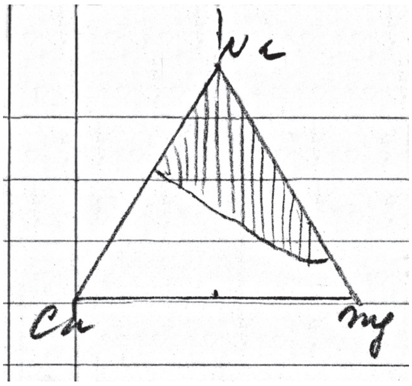


Figure 5.17 Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg. The shaded part of the triangle shows potential environment for fungus Oöspora.

5.7.9 Lochmiopsis sibirica Woron (= Ctenocladus circinatus Borzi)

J. Ruinen, PhD Dissertation, Leiden (1933).

[Baas Becking inserted Fig. 5.18, potential environment for three chlorides for *Lochmiopsis sibirca*, based on Figure X.18 in *Geobiologie* (2016). See also Figs. 5.17, 5.19b and 5.20.]

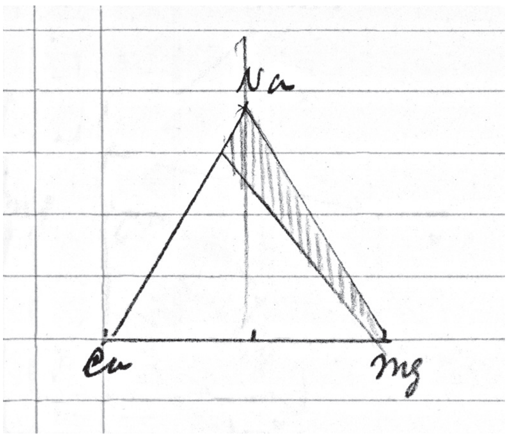


Figure 5.18 Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg. The shaded part of the triangle shows potential environment for *Lochmiopsis sibirica*.

5.7.10 Dunaliella viridis Teod

Baas Becking (1930, 1931a and 1931c).[56]

[Baas Becking inserted Fig. 5.19a and 5.19b, Antagonism of *Dunaliella* between calcium and magnesium with evaporation of seawater, based on Figure X.20 in the 2016 edition of *Geobiologie*. In Fig. 5.19b he also indicated the potential environment for *Dunaliella* for three chlorides. See also Figs. 5.17, 5.18 and 5.20.]

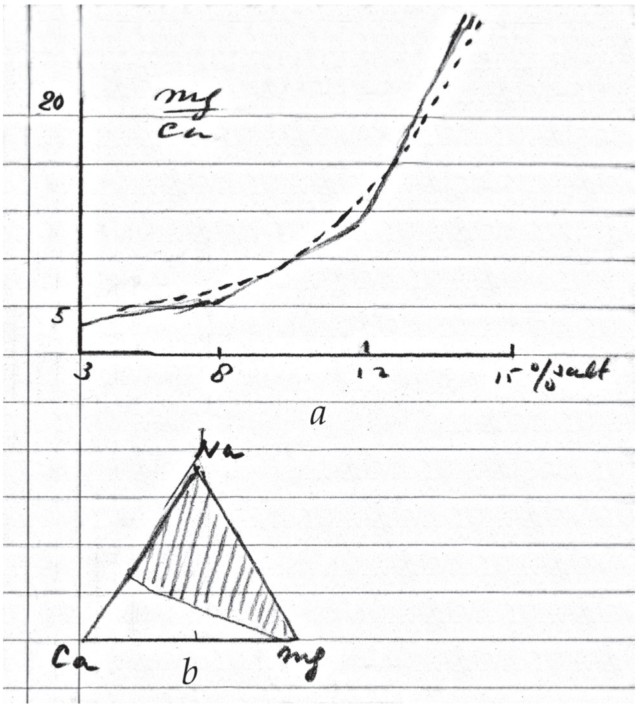


Figure 5.19 **(a)** *Dunaliella*, antagonism between calcium and magnesium with the evaporation of seawater (taken from Baas Becking, 2016, Figure X.20). **(b)** Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg. The shaded part of the triangle shows potential environment for *Dunaliella*.

5.7.11 Other salt organisms, algae

Chaetomorpha linum (J. de Zeeuw, PhD Dissertation, Leiden, 1937).[57]

[Baas Becking inserted Fig. 5.20, in which he indicated the potential environment of *Chaetomorpha linum* and other algae salt organisms for three chlorides. See also Figs. 5.17, 5.18, 5.19a, and 5.20.]

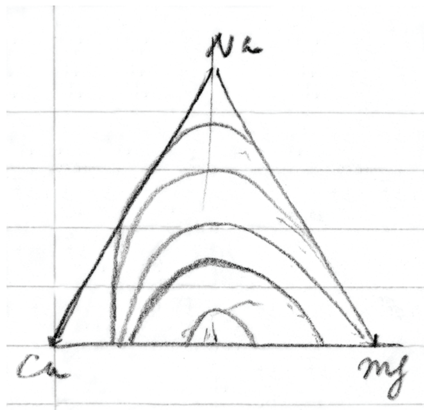


Figure 5.20 Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg. The shaded part of the triangle shows potential environment for *Chaetomorpha* and unspecified salt organisms and alga.

56 Baas Becking referred to his *Dunaliella* experiments which he presented at the Hopkins Marine Station in December 1929 at the Midwinter meeting of the Western Society of Naturalists (Baas Becking, 1930). The results of his experiments were further published in *The Journal of General Physiology* (Baas Becking, 1931a) and in *The Scientific Monthly* of May 1931 (Baas Becking, 1931c). See Oren (2011, p.13-17) for a discussion of Baas Becking's experiments with *Dunaliella*.

57 Reference to Jetske de Zeeuw (1939).

58 Possibly reference to Jacob Reitsma (1932), who defended his PhD dissertation, Studiën über Armillaria Mellea (Vahl) Quél. in Utrecht (supervisor Johanna Westerdijk). Also reference to Booij (1940), The Protoplasmic Membrane Regarded as a Complex. PhD Thesis, Leiden. H.L. Booij defended his Leiden thesis in 1938 (supervisor H.G. Bungenberg de Jong), it was published in 1940.

5.7.12 Pollen grains

The unpublished work of Reitsma and also Booij have shown that the pollen of sweet p[illegible] germinating in fine cane sugar solution is g[illegible] by $CaCl_2$ in concentrations up to [50 m.eq].[58]

[PhD Dissertation, Booij (1940)].

[Baas Becking inserted Fig. 5.21, based on the dissertation of H.L. Booij, in which the potential environment was indicated for the germination of *Lathyrus* pollen for a mixture of three chloride solutions. See also Figs. 5.17, 5.18 and 5.19a.]

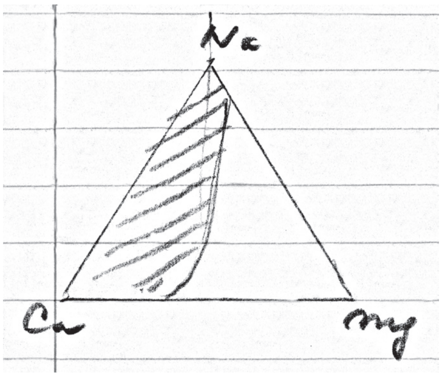


Figure 5.21 Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg. The shaded part of the triangle shows potential environment for the germination of *Lathyrus* pollen, taken from the PhD thesis of Booij (1940).

5.7.13 Theory of antagonism

Theunissen.[59]

5.7.14 Summary and conclusions

[Baas Becking inserted Fig. 5.22, a rough sketch that is a summary of the foregoing paragraphs on the potential environment of various organisms in mixtures of chlorides. The sketch was copied from Figure X.18 in *Geobiologie* (2016).]

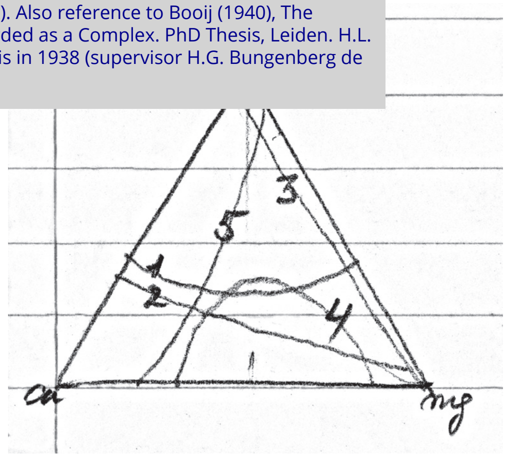


Figure 5.22 Rough sketch of equilateral triangular plot of salt solution with cations Na – Ca -Mg at 1 M total concentration for *Dunaliella* (line 1), *Artemia* (line 2), *Lochmiopsis* (line 3), *Chaetomorpha* (line 4) and Lathyrus pollen (line 5). From Baas Becking (2016, Fig. X.18).

5.8 Adaption

5.8.1 Introduction

If the milieu should act directly on the genome, we might expect a world extremely Lamarckian. The imprint of the milieu would result in a hereditary effect. Although many Latin biologists adhere, in some modification or other, to Lamarck, experimental evidence, however, has in no case substantiated this theory. (Claims to a Lamarckian origin of hereditary change, such as from Guyer[60] and Kammerer[61] have been disproved). We find ourselves, therefore more or less in a quandary. There is no doubt that organisms fit into their milieu, a survival of the fittest cannot account for the presence of highly specialised organisms in a highly specialised milieu, as the probability to live is so infinitely small as compared with the probability to miss. Still all attempts to demonstrate a direct action of the milieu upon the genome have failed. There is, probably, an indirect action (indirect in as much it bears no relation to the fitness of the new genome to the milieu) of both cosmic rays and certain chemical substances of the colchicine or acetophenone type. Cosmic rays seem to promote mutations, at least in Drosophila, which the colchicine-like substances may cause polyploid mutants to occur (Krythe and Wellensiek, 1943).[62] By examining the

58 Possibly reference to Jacob Reitsma (1932), who defended his PhD dissertation, *Studiën über Armillaria Mellea* (Vahl) Quél. in Utrecht (supervisor Johanna Westerdijk). Also reference to Booij (1940), *The Protoplasmic Membrane Regarded as a Complex*. PhD Thesis, Leiden. H.L. Booij defended his Leiden thesis in 1938 (supervisor H.G. Bungenberg de Jong), it was published in 1940.

59 Reference to Theunissen (1936), *Lyophiele niet Amphotere Bio-kolloiden Beschouwd als Electrolyten*. Thesis, Leiden. Theunissen's work and that of his teacher Bungenberg de Jong and colleagues H.L. Booij and J.G. Wakkie in Leiden, was concerned with the reversal of charge of biocolloids with salt mixtures. They studied the phenomenon in physiology that some cations may antagonise the action of others. In the 1953 version of *Geobiology* (1953a, p. 284) Baas Becking referred to:

> Dr. J. Wakkie has shown in the Leyden Laboratory (1932, unpublished) that various simple Chlorophyceae are sensitive to cations in low concentrations.

Baas Becking co-authored: Bungenberg de Jong, Vander Meer and Baas Becking (1935), *Kolloidmodelle zur Illustration Biologischer Vorgänge I. Dreisalzeffekte bei der Keimung von Krustentiereiern und bei Phosphatiden*.
See also Booij and Bungenberg de Jong (1956, p. 23-25).

60 Michael F. Guyer (1874-1959) and Elizabeth A. Smith performed experiments attempting to demonstrate Lamarckism (Guyer and Smith, 1920). Their experiments were criticised and were not repeated by other scientists.

61 Paul Kammerer (1880-1926) Austrian biologist advocated Lamarckism. He was accused of fraud for his experiments with midwife toads. Six weeks after the accusation Kammerer committed suicide.

62 In 1942 Krythe and Wellensiek of the Institute for Plant Improvement, in Wageningen the Netherlands, were able to report that polyploidy had been induced by colchicine in 243 species. After reviewing the literature from 1937, they were able also to state, however, that the results of artificial polyploidy had been largely over confident and over optimistic. Krythe and Wellensiek (1942). See also De Chadarevian and Kamminga (2005).

actual nature, however, we are struck by the remarkable fit of external and internal milieu, a fit that none of the theories mentioned may explain. Ignorabimus![63]

5.8.2 Teleology

This word is the bugbear of many biologists, and the concept of teleology has indeed been treated often in an unscientific way, implying a function for every conservable biological structure. In this direction the inspiring book of Haberlandt, *Physiologische Pflanzenanatomie*,[64] has gone perhaps a bit too far, to be silent about many investigations on flower biology. However, living beings behave not aimlessly, they apparently strive for some goal. The goal, the end the aim, lies primarily in themselves, as already Aristotle recognised. The concept of *entelechy* (H. Driesch),[65] should be taken more seriously than most workers seem to do, in as much as it is really capable to stimulate further research. For what is "vital pressure", *élan vital*, but our expression of our *entelectric* principle? From this tendency for self preservation (self used here as the species rather than the individual) we arrive automatically to teleological ideas. Adaptation is a change, a useful change, therefore teleological, of an organism. It is a change caused by the milieu. It seems as if such a change is often hereditary and then we are up head and shoulders into Lamarckians. For it is different if a variation range of a given organism is large enough to select from (Darwin) or whether as a given pattern, a new pattern is superimposed.[66]

5.8.3 Terminology

The word "physiological artefact" was coined by A.J. Kluyver and J.K. Baars, to describe sulphate reducing bacteria, isolated from natural surroundings, which proved to be thermophilic.[67] Did the physiological experiment add something intrinsically new? Did the microbe *mutate*, or was there first a selection from a mass of variants, some of which die off because their potential milieu did not cover the conditions? We cannot strictly speak about mutation in microbes, for there is no sexual reproduction. Vaas has coined the word hypartype corresponding to phenotype and doxatype corresponding to genotype, instead of mutation he uses the word pedema.[68] According to Kluyver we have a cell *A*, potentialities *a*, changing into *A*, potentialities *b*. According to the statistical theory cell *A* would give rise to cells of potentialities *a* - - - *z*, out of which only a few meet their proper milieu. It is the *process* of adaptation that is difficult to understand in Kluyver's theory.[69]

5.8.4 Adaptation bacteria

Vaas (1938) has studied the effect of variable salt concentrations upon the growth *of Bacillus megatherium* de Bary (Fig. 5.23). This spore-former is a large rod, often in clusters or strings. The growth curve from a one spore isolation was in all cases investigated. Starting with a certain inoculum first a *decrease* in numbers (established nephelometrically) could be found. Later we see the so called "logarithmic phase" (Rahn, Buchanam and Fulmer) of growth, then a slackening off, a

63 '*Ignoramus et ignorabimus*', meaning 'we do not know and will not know': scientific knowledge is limited.

64 Gottlieb Haberlandt (1854-1945), Austrian botanist who wrote *Physiologische Pflanzenanatomie*, published in 1884 (Haberlandt, 1884). This book inspired Hugo de Vries. Haberlandt combined the results of the physiological processes of organs, where physical and chemical laws are guiding, with the interaction with the anatomy and function of organs. So, he made a difference between processes in the animate and inanimate nature. See Zevenhuizen (2008, p. 182-183).

65 Hans Driesch (1867-1941), German biologist and philosopher. Driesch, believing that his results compromised contemporary mechanistic theories of ontogeny, instead proposed that the autonomy of life that he deduced from this persistence of embryological development despite interferences was due to what he called entelechy, a term borrowed from Aristotle's philosophy to indicate a life force which he conceived of as *psychoid* or 'mind-like', that is; non-spatial, intensive, and qualitative rather than spatial, extensive, and quantitative. The scientific community criticised his concept of entelegy.

66 In Section *Adaptation* in the 1953 version of *Geobiology* Baas Becking described "the question of hereditary adaptation" of organisms "in order to make it fit in a new environment" (p. 492-498):

> In practice, however, the issue is clouded by the evaluations of the impact of the two agents, heredity and environment, "nature et nourriture", Blut und Boden", upon the human race; ecclesiastical. creed demanded a voice, especially in the latter part of the nineteenth century and at present we witness the influence of political creed upon the development of what should be a purely scientific matter. The emotionalism connected with any discussion of this problem has coloured, and thus disqualified, some or the recent work. There is no need to comment upon the great importance of Darwinistic evolutionary thought, especially of the selection principle, as a guide for our understanding of the more passive forces in evolution, for evolution requires a continuous re-adaptation to environment.
> The main difficulty seems to be what forces cause this evolution. Is it primarily an inner urge, an inner inevitability, which causes the evolutionary stream to flow and to follow a certain course? Or is this stream directed by the topography the environment? In Section 2 some arguments are given which seem to favour the latter alternative. (See also Umbgrove 1942), In certain geological periods, with sudden changes in climate, periods of orogenesis, sudden veritable explosions of speciation did occur. Was this only the stimulation of the sluggish stream of evolution or the chance of this stream into a new course? And, apart from these evolutionary speculations, is it possible to assume that the "Milieu Exterieur" can permanently modify the hereditary complex?
> It has been repeatedly claimed that this is the case. The stimuli may be traumatic, a chemical or physical nature, apart from the (vague) impact of climate. The evidence for mutagenic influence of traumatic stimuli is very doubtful (Sirks, 1951) Climatological influences have been chiefly established by means of populations instead of with genetically homogeneous material. Here again, convincing evidence seems to be lacking. There is no doubt that a substance like colchicine is able to double or to multiply the number of chromosomes in a nucleus, with the formation of a new genotype. The application of high and low temperatures may also cause a change in chromosome numbers. The influence of radium on the genotype has been conclusively shown for plants.
> The work on the influence of X-rays, initiated by Muller in 1928 (*Drosophila*) has shown that radiation is of great influence on the genotype. It was shown that the largest part of the induced mutations was lethal, but that there is a qualitative analogy between he induced and the natural mutations. Later work has shown that the X-rays are effective on plants. Here temperature shocks and ultraviolet light also induce a high mutation rate in the offspring. Cosmic radiation is also effective, both on the mutation rate in fungi and in *Drosophila*.
> Most of the work performed in this field seems to show only that the mutation rate is increased beyond its natural magnitude by certain external influences (Sirks, 1951). The environmental influence would therefore only stimulate the slow stream of mutations which remain autogenous in nature. The induced morphological changes are, on the whole, unspectacular, and not to be compared to specific (let alone generic) differences met in evolution. We are still waiting for a real clue, and we may be extinct as a race before we can solve this Lamarckian-Darwinistic riddle.

67 Reference to Kluyver and Baars (1932). According to Postgate (1979, p. 5-7):

> Sulphate reducing bacteria include both ordinary mesophilic strains and thermophilic strains able to grow at temperatures between 50 and 70 °C. Kluyver and Baars (1932) believed that these were adaptive variants of the same organism [..] However, Campbell, Frank and Hall (1956) showed conclusively that the thermophilic types were a completely different species, hitherto known as *Closteridium nigrificans* […]. Today, the adaptive interconversion of mesophilic and thermophilic species of sulphate reducing bacteria must be regarded as mistaken.

See also Postgate (1995, p. 16-17) and *Geobiology,* Baas Becking (1953, p. 494):

> According to definition of the milieu, the counter mould of life, the sum total or rather, the integration of environmental factors, we will call the "milieu", every organism adapted to its milieu would be an artifact -, in a physiological, as well as in a morphological sense.

68 Reference to Vaas (1938). See also p. 492-494 in Baas Becking *Geobiology* (1953), Chapter V, Section *Adaptation*:

> Vaas remarks that the terminology, used for higher organisms; genotype, Phenotype and mutation, is not applicable to bacteria as, without a genome, there will be no genotype. He has coined new terms, hypartype and doxatype while he suggests, the neutral term "pedema" (jump) instead of mutation.

69 In manuscript *Geobiology* (1953, p. 495), Baas Becking remarked:

> It is true that the "pedemata" in bacteria (*e.g.*, white form of prodigious) are often reversible, but so are certain mutations in sexual organs. Obviously, in a nuclear organism the question of hereditary adaptation cannot be settled before sexual reproduction has been convincingly shown to exist. […] But the present evidence of such "bacterial mutations" seems unconvincing.

decrease in numbers followed by weak secondary maxima (line a). Line b represents the behaviour when inoculated in 9 % NaCl.[70] The initial decrease is much more marked, and subsequent growth is slower. By ingenious check experiments Vaas (1938) arrived at the conclusion that the probability for the occurrence of halo-tolerant variants depends upon the size of the inoculum. This he interpreted by the plausible assumption that variants of extreme potential milieu occur more rarely than variants of more average potentialities.

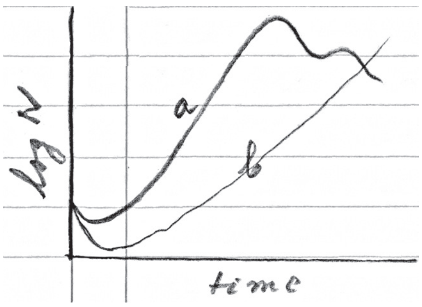


Figure 5.23 Logarithmic growth of population *Bacillus megatherium* in variable salt concentrations. Taken from Chapter VII in Vaas (1938).

[Baas Becking inserted Fig. 5.24.]

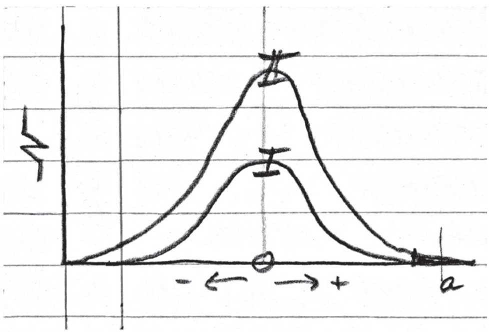


Figure 5.24 Potentiality of variants in population of *Bacillus megatherium* in salt concentration depending on size of inoculum.

At 0, on the abscissa the normal milieu, the variants able to withstand + or – might decrease according to probability law:

$$y = \frac{y_0}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{x^2}{2\sigma^2}}$$

Now we ask for the potentiality +a it is clear that a population I is too small to yield such a variant. We need the sign of population II. From this Vaas (1938) concluded that these are no physiological artifacts, but only selection of extreme variants. (See however, the work of T. Hof, thesis, Leyden, 1932 on the halotolerance of urea bacteria).[71]

5.8.5 Higher organisms

Heredity enters in here and with heredity comes phylogenetic and ontogenetic speculation. We meet with Darwinism. When selection is made by the milieu from a number of *non-directed* variants (as in the case of the halophilic bacteria), we meet with Lamarckism, where the milieu causes a directed change in the genome. Further we meet with the hybridisation theory of Lotsy and with mutations.[72] Hybridisation may increase vigour as well as range of variability, but does not introduce the elements expressing the *directive* influences of the environment. So, speak about mutation only to refer to a sudden change in the genome, usually a loss mutation, while most adaptations, teleologically and biologically, are anything but loss mutations. By what curious process did the organism fit into its environment? Certainly, there must be discovered a new principle, for what we have does not suffice. Why is the eye of the water beetle *Gyrinus* partly adapted to land and partly to aquatic life?[73] How may we possibly account for such things?

5.8.6 "Fremddienliche Zweckmässigkeit" [Expediency for other purposes]

This expression was coined by Troll (?) for, I believe, the relation between gall formation and the gall insect.[74] In gall formation we meet with a typical "ergon" action of the gall insect. In certain cases (Annand and Baas Becking, *Science,* 1925) galls have been produced artificially (cabbage leaves, ammonia vapour).[75] However, the insect must *secrete* the *specific* ergon to stimulate the plant tissue to make the gall. For a detailed description of the gall formation through the agency of *Cynips*, the classical memoir of Beijerinck should be consulted.[76] Zweckmässigkeit [Expediency] implies teleology, but what of that? The plant reacts in a way such as to further the ends of the animal, and without its reaction to the injection the insect could not produce larvae from its eggs. The insect is "adapted" to the plant, the plant to the insect.

5.8.7 Mimicry

Admission of the existence of mimicry, apart from a negative "selection of the unfit" of the unprotected, is tantamount to an admission of ignorance as to the cause of an orchid flower is able to imitate a female digger wasp, inclusive of the specific odour (which odour attracts the male digger wasp). It seems a phenomenon so far removed from any attempt at rational explanation, that we are reduced to a state of more or less dumb admiration. This is, perhaps, an unscientific

70 Reference to Otto Rahn (1881-1957), German-American microbiologist and R.E. Buchanan (1883-1973), American bacteriologist and Ellis Ingham Fulmer (1891-1953), American biophysical chemist Iowa State. Fulmer and Buchanan, professors at Iowa State College, wrote the three volume treatise *Physiology and Biochemistry of Bacteria* (1928-1930). Volume I (1928) dealt with growth phases.
See also Rahn (1930), Rahn (1931).

71 Reference to Hof (1935a and 1935b).

72 Johannes Paulus Lotsy (1867-1931), Dutch botanist, Professor of Botany, Leiden University (1904-1909) director Rijksherbarium Leiden (1906-1909), secretary Dutch Society of Sciences Haarlem (1909-1931). Zevenhuizen (2008), gave a detailed description of Lotsy's controversy with Hugo de Vries (p. 362-370) and Lotsy's doubts on De Vries mutation theory (p. 375-376).

73 *Gyrinus natator*, whirligig beetle. Their compound eyes are remarkable for each being divided into a higher part that is above water level when a beetle is floating passively, and a lower part that is below water level. See also Blagodatski. *et al.* (2014).

74 The reference to Julius Georg Hubertus Wilhelm Troll (1897-1978) is wrong. The term "*Fremddienliche Zweckmäßigkeit*" was coined by Becher (1917), *Die fremddienliche Zweckmäßigkeit* der *Pfanzengallen und die Hypothese eines überindividuellen Seelischen.*

75 Unidentified reference, not found in the 1925 issues of *Science* or in the bibliographies of Baas Becking and Annand. Baas Becking probably referred to Percy Nicol Annand (1898-1950) an entomologist, who wrote a M.A. thesis in the Department of Biological Sciences at Stanford University in 1922. In 1928 he received a Ph.D. in zoology and botany from Stanford. He described the gall inducing species of the family *Adelgidae* (Annand, 1928). In 1941 he was appointed as Chief of the US Bureau of Entomology and Plant Quarantaine.

76 Reference to Beijerinck (1897).
For a review of Beijerinck's studies on galls see van Iterson (1940).

point of view to take, but it seems to the author that the safe, so called scientific view is a hothouse flower, a product of the laboratory, where we select our problems arbitrarily and shrew the complicated ones.

A photographic picture; no – more than a photographic – a three dimensional picture of one organism has to leave its literal imprint upon the genome of another, so that the other shall wear the livery of the first. This as far as the efficient cause, and not the final, is concerned. The final cause is much more the component – mimicry is camouflage, an attempt to pass for somebody else. The final cause is, however, also, far more obscure. For who or what not only perceives the likeness between A and B, but is also able to create likeness and unlikeness?

Is not Francis Bacon right when he proclaimed final causes, like vestal virgins, as sterile and dedicated to God? For sterile is all our speculation upon these, and analogous matters. But certainly, it also points to an origin as far distant from our modern knowledge as the genetic relation is between the birch moth and the birch, or the Sphinx and the honeysuckle. In a sense these phenomena only allow for a transcendental explanation, as they transcend our understanding. All experiments upon the formative influence of the milieu have failed. Kammerer's claim, that salamander (*Axelotls*?) raised in a dark aquarium and consequently dark skinned, produced dark skinned progeny, was based upon a falsification.[77] We stand utterly helpless to account for the simplest instances of obvious adaption. And we may not look the other side, for the phenomenon persist? And they belong to the realm of biology?

5.9 Minimum Elements

Geochemically it seems rather arbitrary to talk about minimum (or trace) elements. For the frequency of many of the 'common' biological elements (like carbon) is geochemically speaking, quite low, while geochemically common elements (nickel, titanium) appear as biologically rarities.

In this section we shall only deal with the beneficial effects and with the accumulation of the following elements:

Li, B, F, Ti, V, Mn, Fe, Co, Ni, Cu, Zn, As, Br, Mo, Sb and I.

There are references to other elements as well in the vast and rather secluded literature on the subject (Edelman, Goldschmidt). An element may be called "rare" when its dissipations lag is light (dispersion of Edelman).[78] This dissipation is again determined by its process of isomorphic replacement (Goldschmidt, 1923), meaning that a certain element may replace another, commoner, in its space lattice, if the ionic radii are of almost the same size. Due to this fact iron, which is really a *central* terrestrial element, 'creeps up' into the sima as its ionic radius is so close to that of magnesium. Due to its isomorphic displacement, again manganese replaces the iron in minerals. Many rare elements obtain, by this process a wide, but diffuse, distribution.

Often, the rare elements act in very low concentrations and are not further concentrated by the organism. Here is therefore a great difference between "éléments concentrateurs" (Vernadsky) and "rare elements." In several desert plants, *e.g.*, *Astragalus*, selenium, may accumulate to such an extent that it causes severe cattle diseases ("locoweed") (Beyers, 1935) [= Byers, 1935].[79] In order to explain the action of minute quantities of boron on sugar beets, Brandenburg (1931 or 1939) assumes that a boron atom is placed at the end of a long chain molecule, changing the properties of this molecule.[80] As to the mode of action of the rare elements we are entirely in the dark. What surmises seem plausible are mentioned in the text.

Lithium. Good cigar contains Li (Bunsen).[81] Young (1935) 110 γ/L [10^{-6} g/litre] in seawater.[82] In some instances, seems to be able to replace other alkali metals (Gellhorn).[83]

Boron. Heart rot of sugar pest. Top disease of tobacco fertility fruit trees. Growth of pollen tubes cocoa. 4.7 mg/litre in seawater (borates change drive of CO_2 in seawater). In mineral boracite $Cl_2Mg_6B_{14}O_{26}$. In salt 0.89 % B_2O_3. Palaeozoic slates only 0.1 %. In the ash of plants 0.5-1 % B_2O_3. Anions of seawater, according to Errena, not out of eruptive rocks (for Na/Cl, in ocean 1.05/1.09, in erythrocytes 285/4.8; or 0.5 to 59.4). Boron probably from volcanic exhalations.

Fluorine. In *Trichoderma koningii* (Niethammer).[84] All iron in seawater as fluoride. Bad effect on teeth. Seawater 1.4 mg/litre. Klement (1938) has shown marine anemones more fluoride in bone and teeth.[85]

Table 5.2 Percentage fluorine in mammals, birds and fishes.

	Land	Marine	Bones and teeth
	%	%	Oyster 0.02 %, André (1909)
Mammals	0.05	0.55	Fluorite CaF_2 common
Birds	0.11	0.32	In limestones
Fishes	0.03	0.44	Cryolite $NaAlF_4$
Also in apatite			

77 See for Kammerer, van Alphen and Arntzen (2016).

78 Reference to Cornelis Hendrik Edelman (1903-1964), Dutch professor in Mineralogy, Petrology, Geology and Agrogeology in Wageningen. Baas Becking probably referred to Edelman (1936). Edelman described the term "rare" as "finely divided material dispersed in small quantities." Apparently, the Section on *Minimum Elements* in the present version of *Geobiology* were strongly inspired by Edelman's article.

79 Reference to Byers (1935). See also White (2016).
'Locoweed' is a poisonous plant problem, in the case of *Astragalus crotalaria* due to Se hyperaccumulating.

80 Baas Becking possibly referred to E. Brandenburg who showed in Holland that crown rot of sugar beet is caused by boron deficiency, and can be cured by the addition of this element. See Brandenburg (1931), Brandenburg (1939).

81 The Cuban soil is high in lithium and thus the cigars have lithium in them too. Hans Goldschmidt in his *Erinnerungen an Robert Wilhelm Bunsen* (1911), tells the anecdote that as a student he was allowed to make spectral analytic experiments in Bunsen's laboratory.
As Bunsen was a smoker of strong Havana's he never failed to point out that in every Havana you could clearly see the red lithium line. If, by chance, a student himself had a cigar which showed no lithium reaction, Bunsen can scarcely ever have missed the opportunity of making a little joke, by pointing out that the student's cigar was no Havana.
Robert Wilhelm Bunsen (1811-1899), German chemist, he investigated emission spectra of heated elements and discovered caesium (1860) and rubidium (1861).

82 Reference to Richard V. Young, Chemical Laboratory of Iowa State College, who published in the 1930s with Henry Gilman several papers on lithium in the *Journal of the American Chemical Society*. Baas Becking's reference to Young (1935) was not identified.

83 According to Gellhorn (1929):
"Die Ionen der Alkalimetalle werden stärker aufgenommen als die der alkalischen Erden. Die Kationen bilden dabei eine Reihe: K > Na > Li > Mg > Ca, und die Anionen folgende Reihe: CnS > Br > J > NO_3 > Cl > SO_4."

84 Reference to Anneliese Niethammer (1937).

85 Reference to Klement (1938).

Titanium. In nature as ilmenite $FeTiO_3$ and its weathering product, titanite $CaTiSiO_5$. Further pseudobrookite, peridotite *etc*. Rutile is TiO_2, anatase and brookite same composition.

Vanadium. In primitive Chordates (Tunicates). In seawater 0.3 γ/L [10^{-6} g/litre]. In asphaltic ash (Longobardi). Large amount in *Amanita muscarina* (according ter Meulen, see Edelman, 1937).[86]

Clarke (1916, *Data of Geochemistry*) cites much older literature (p. 712).

Baskervill in ashes peat N. Carolina.

Musingaye in ash coal and oil bearing shales.

Bertin in ashes of plants.

Byle, in lignite from San Rafael, Argentina. Ash 38.22 % V_2O_5.

Momlot, in similar coal, 38.5 % V_2O_5, Torrico and Meck, from Yanli, Peru 38 %. "Grahamite" (oxokenite) from Oklahoma, Wills found 12.2 % V_2O_5 in ash. Nevada asphalt 30 % V_2O_5 in ash.

"Plants have played some part in the concentration of vanadium" (also uranium, see Clarke,1916 , p. 717).

Cabriolite = uranium, vanadrite. Vanadium found in fossil plants (Boutwell).[87]

Manganese. In enzymes?

Redox- classical oat disease.[88]

Cocoa, tea and coffee are Mn plants, also rice.

Leo Minder Der Zürichsee im Lichte der Seetypenlehre. *Neujahrsblatt Naturforschende Gesellschaft*, Zürich, 145 (1943).[89] Mn accumulation 120 m observations, star shaped colonies ±10μ, *Leptothrix echinata* Beger. No iron at all. "gemeβter Sauerstoffgehalt verbunden mit grösser Vegetationsdichte." When brought at the air colonies become visible by manganic ion formation. Enormous mass, apparently heterotrophic. When no bacteria present 130 m deep 0.4-0.95 mg/litre. Mn, no iron in vegetation.[90]

Cobalt. In seawater, in rivers, in soils, in salt. Askew has called attention to a curious anaemia in sheep (1936) in New Zealand, which was later observed by Marston in South Australia and also in South Africa. A few milligrams of $Co(NO_3)_2$ clearly sufficed to cure the disease. It was found that, from certain soils, due to deficiency in Co (or high alkalinity!) the grass contained almost no cobalt.[91] Tried for pernicious anaemia in man without success. Always accompanying iron.

Saporcite CoS, bieberite $CoSO_4.7H_2O$.

Linnaeite Co_3S_4. However, nearly all igneous.

Nickel. In ash of certain asphalts (Longobardi, 1935). 0.1 γ/L [10^{-6} g/litre] in seawater. Accumulated by unknown flora and fauna (Edelman). Always accompanies iron.

Millerite NiS, polydimite Ni_4S_5

Beyridite Ni_3S_4, morenosite $NiSO_4.7H_2O$!

However, nearly all igneous.

Copper. In polyphenoloxide 6.29 % Kurbowitz. In haemocyanine 0.17 %. As anti-araemia in Goitre

"lich disease" of cattle. Colonising disease. Oysters 3 g/kg, in seawater 5 γ/L [10^{-6} g/litre].

Chief ore: native copper, several sulphides, two oxides, and two carbonates. Sulphate also exists.

Pyrolunite is the chief sulphide. There is an indication that it may be found microbiologically from the sulphate, as in zinc. Chemobiological investigation of mine water might yield interesting results.

Zinc. In enzymes. Widely diffused in rocks, ZnS chief in seawater 5 γ/L [10^{-6} g/litre], ore sphalerite and wurtzite. Clarke (1916, p. 677). In N. St. Louis, Wheeler found massive zinc embedded in lignite where it had evidently been formed by the reducing action of organic matter upon other zinc compounds. In Galena, Kansas, zinc as ZnS precipitated by organic action? Also, goslanite $ZnSO_4.7H_2O$ occurs. (Thiooxidans?)

Fruit trees, citrus fruit.

Arsenic. Raulin (1869) showed that *Aspergillus* was greatly stimulated by small amounts of As_2O_3 with nutrient medium 15 γ/L [10^{-6} g/litre] in oceanwater (see Clarke, 1916, p. 695 for natural occurrence in lithosphere).[92] It may well be that arsenic, like nitrogen may be reduced to AsH_3 by several fungi. In the older literature there are cases described of green wallpaper in which moulds, introduced by and living in the paper hanger's paste liberated AsH_3, thus causing pathological effects upon the dwellers in the room. According to others, however, certain other organic compounds of arsenic are the cause of this phenomenon. In any case As^{3+} and not As^{5-}.

Bromine. Alga, up to 1 % dry substance, *Antozoa* up to 4 %. In the latter case as 3,5 dibromopyridine. From the mantle of the purple snail 6,6, dibromoindigo. The origin of slugs? Seawater 6.0 mg/litre. Bromine is commercially made out of seawater. It is one of the most abundant minimum elements, and might be mentioned as an élément concentrateur only for a few organisms as the bromine extent of freshwater organisms, land plants and higher animals is very small.

Strontium. In radiolarian shells $SrSO_4$, suborder *Actipylea*, genera *Actinellus, Acanthociasma, Acanthometron, Acanthonia, Amphilonche, Sphaerocapsa, Diploconus* (Kudo, p. 138 and p. 871).[93]

86 For Edelman see above. Baas Becking had his reference to Longobardi (1935) from Edelman (1936).
The fungus *Amanita muscaria* concentrates high levels of amavadine, a natural vanadium complex without the V = O bond.
Henri ter Meulen (1871-1942), since 1905 Professor in Analytical Chemistry, Technical University. Delft. Ter Meulen (1931) found a remarkable accumulation of vanadium (120 ppm dry weight) in *A. muscaria*.

87 Baas Becking referred to information on vanadium from J.M. Boutwell in Utah in Clarke, 1916 (p. 716-717 in the 1920 fourth edition of Clarke's *Data of Geochemistry*).

88 Manganese is an essential plant micronutrient. Mn toxicity and deficiency in plants are documented. In practice there is a delicate balance between the microbial oxidation of Mn^{2+} and the reduction of Mn oxides, which can be shifted by small changes in soil water potential along with changes in water temperature and pH. See Sparrow and Uren (2014).

89 Baas Becking also referred to Leo Minder in Section 8..5.5.

90 Reference to Beger (1935), *Leptothrix Echinata, ein Neues Vorwiegend Mangan fällendes Eisenbakterium. Leptothrix* is an aerobic chemolitotrophic bacterium that uses Mn^{2+} for Manganese oxidation (MnO_2).

91 Reference to the work of H.O. Askew and H.R. Marston on 'Coast disease' of sheep in New Zealand and South Australia. Due to cobalt deficiency. See for a review and literature references; Beeson (1950).

92 Reference to Raulin (1869). Raulin demonstrated the essentiality of salts of Zn, Fe and Mn as well as silicates for the growth of *Aspergillus niger.* We found no reference to the stimulating working of arsenic.

93 See Kudo (1954), *Protozoology.* Baas Becking doubtlessly used an early edition.

13 mg/L in seawater. Celestine = $SrSO_4$. A. Koch found them in bitumen ores limetree (Clarke , 1916, p. 581) together with barite several other cases. In ashes of seaweeds, and Vogel found it in corals and molluscan shells. The find in the *Radiolaria* is due to O. Bütschli (1907).[94]

Molybdenum. H. ter Meulen (1931). In brain, liver *etc*. Bortels (1930). *Azotobacter*, later also for *Radiobacter*.[95] In enzymes? In seawater 0.5 γ/L [10^{-6} g/litre]. Perhaps necessary for any N fixation? Principle ore is the sulphide. Molybdenite MoS_2, often associated, in sedimentary limestone. With pyroxene. Calcite, mica, pyrite *etc*.

[crossed out:] Antimony

Calcium iodate, lanthanite, in Chilean nitre beds (the calcium ion and the iodine ion have similar ionic radiii and may therefore occur in the same lattice, according to the principle of V.M. Goldschmidt).

Iodine. Di-iodotyroxine in thyroid. Seawater 50 γ/litre. Sponges, algae, *Lamnaria* 0.6 % iodide and iodate. Rain water 0.2-5 γ/L [10^{-6} g/litre] , also river water. 70 % from Chilean saltpetre (iodate, got oxidised in NaCl), 30 % from algae.[96] Goitre, iodised salt, mountain districts, N. S. Holland, Java. [97]

Diagnosis (Mulder) by means of fungi, Cu, Mn. Mulder thesis Wageningen (1938)?[98] Certain fungi ([*Aspergillus niger*]) need manganese and copper for their development. By careful experimentation the author has elaborated a method by which pure strains of the fungi are used as indicators in quantitative determination of traces of both of these metals. The method could be extended to a molybdenum determination by means of *Azotobacter*! *etc*.

Text box 5.3 – Baas Becking notes made prior to writing the manuscript

Beijerinck, later H.G. Derx, *Bact violaceum*. Slime of bread, next to trickle of the tap![99] *Sarcina* (see also J. Smit).[100]

5.10 Specific Milieu and Vital Explosions

5.10.1 Introduction

Vernadsky (*La Géochimie*) speaks about "explosions vitales", vital explosions.[101] When population growth remains a few generations longer in the logarithmic phase (see Sections 4.1.3.and 1.4) these explosive plagues may result. Why is the increasing, or stationary natality not checked by increasing mortality? There may have been abundance of a factor which is a usual minimum factor, there may be an absence of influence inimical, as parasites or consumers, there may have been a combination of the two. But one thing is certain, periodically the locusts come, and the rust, and the plagues and the red death, and perhaps, like the lemming, we, ourselves are recurrent pests, in this day again in explosive ascendency.

5.10.2 Plagues, epidemies

Nicolle (1930) [see also Section 5, note 114] has compared the epidemic to an organism. These are necessary for its occurrence a syndrome of phenomena. It starts slowly, slowly it gathers momentum, it breaks all bounds, then it slackens down, remains stationary and, after a few spasmodic flakes often it becomes non-virulent again and dormant in a few carriers.[102]

5.10.3 Water supplies

Epidemies occur in reservoirs with almost maddening regularity. Algae of the *Chlamydomonas*-type are the most difficult to combat (Whipple). Recently Van Heusden has given a milieu analysis of the water blooms in the Amsterdam Municipal Water Supply.[103] A classic remains the early work of Hugo de Vries on the organisms that live in the subterranean reservoirs of the Rotterdam water supply (1887). De Vries mentions the occurrence and the role of *Bryozoa, Spongilla*, and chief of all *Crenothix polyspora*, an iron bacterium.[104] The epidemies here, as in other cases, are only disturbed links in a cycle – a cycle which, for some reason or other, is temporarily out of its equilibrium. Epidemiology is never the science of one organism by and in itself.

94 Reference to Otto Bütschli (1848-1920).

95 Ter Meulen (1931) succeeded in separating and estimating the molybdenum present in various plants and animals. See also H. ter Meulen (1932), Distribution of Molybdenum. *Nature* 130, 966.
Bortels (1930). Bortels first established the importance of molybdenum and vanadium for nitrogen fixation, and also noted, albeit only in a footnote, that *Azotobacter vinelandii* could grow in the absence of both Mo and V. See Pau (1993).

96 The extraction of iodine from Chilean nitrate was before WWII the main source of iodine. The main difference between sodium iodide and sodium chloride is that sodium chloride is composed of a chloride ion bonded to a sodium ion whereas sodium iodide is composed of an iodide ion bonded to a sodium ion. Sodium iodate can be oxidised to sodium periodate by strong oxidising agents: $NaIO_3 + NaOCl \rightarrow NaIO_4 + NaCl$.

97 Goitre is swelling in the neck resulting from an enlarged thyroid gland. Over 90 % of goitre cases are caused by iodine deficiency.

98 Mulder (1938). Mulder used in his tests the colour of the spores of *Aspergillus niger* grown in a copper deficient medium supplied with small amounts of soil as a measure of Cu supply to the fungus. This served as a measure for the availability of Cu to cereal plants growing on newly reclaimed peaty and heath soils.

99 Baas Becking referred to a personal communication of H.G. Derx.

100 Reference to Jan Smit (1885-1957), Professor of Microbiology, Wageningen (1936-1956). The reference is to Smit (1930) and possibly also to Smit (1933).

101 V.M. Vernadsky was with Lotka (1924) and Henderson (1913) one of Baas Becking's main inspirators for *Geobiology*. Here he referred to the first part of *La Géochimie* (1924). In the 1998 English version, *The Biosphere* (translation of the original edition in 1925 in Prague), the vital explosions are treated in the paragraphs 25-33.

102 In the 1953 version of *Geobiology*, Section on *Man in Relation to Pathogenic Organisms* (p. 701), Baas Becking included a reference to:
Hans Zinsser in his remarkable book on *Rats, Lice and History* (1935) has sufficiently stressed the importance of certain pathogens in human history, which is still taught as a story of battles, treaties and conventions, although the factors of plague, malaria, spotted typhus and tuberculosis have been more potent than many a human plan.
Human history has been punctuated by epidemics. Homer mentions a plague epidemic during the Trojan war, and the black death of 1346, which killed at least three quarters of the population of Europe is still remembered. Epidemics have continued in the intervening centuries, and the last fifty years can show most striking examples as the outbreaks of yellow fever at Panama, of dengue at Athens and of typhus in the Balkans. Human health and population growth have been greatly affected, both quantitatively and qualitatively by the recognition of pathogenic agents and by the means devised for their control.

103 Reference to Dr. G.P.H. van Heusden, biologist of the Amsterdamse Waterleiding. He obtained his Utrecht PhD in 1943 on a study of the migration of glass eel to Lake IJssel: *De Trek van den Glasaal naar het IJsselmeer.*

104 See for Hugo de Vries' research in Rotterdam, Zevenhuizen (2008, p. 142-143, and note 99 on p. 554).

5.10.4 Diatoms

The author had described an epidemic of the centric diatom *Aulacodiscus kittoni* Arnott at Copalis beach, Washington in 1925. The same diatom was found in masses on the beach in Corinto, Nicaragua, by the author in 1928. Van Heurck mentions the mass occurrence of this species at the mouth of the Congo River. It may well be that it is the abundance of silica after the spring freshlets near the mouth of a large river, which temporarily lifted one limiting factor to the realm of the unlimited. Given sufficient phosphate and nitrate, combined with the enriching influence from the freshwater, the milieu conditions for *Aulacodiscus* were fulfilled. (See Baas Becking, Tolman, Hashimoto, 1925).[105] Other diatoms, like *Melmina*, may cause analogous phenomenona (Mare sporco in the Mediterranean).[106]

5.10.5 Jellyfish

Passed a patrol of luminous jellyfish, spring 1927, near Bay of Tehnantepec in Mexico, 120 miles wide (at least).[107]

5.10.6 Locusts

C. Wiman *Palaeont* … 1 (1914),[108] 150. Dr W. Sillig, *Natur u Museum* 57 (1927, p. 94), Russia every 6 years. *Pachychilus tartarea* and *P. migratorius*.[109] See also *Brehms Tierleben* II, curious *coin* commemorating Anno, 1693 (Fremde Herstrecken in Deutschland gesehen), above: "Ein Diener der Herren der Herrscharen."

5.10.7 Mice

Samuel 6: 5. Philistines *vs*. David, Golden mice when they sent the ark back.[110]

California, Wieringen, followed by enormous quantities of birds of prey.[111] Mice may follow grain, or bumblebees or both.

5.10.8 Spiders

[Former island] Urk in 1934. The spider plague after the closing of the Zuyderzee may have followed the *Chironomus* epidemic which occurred because there was no bottom fish to clear the larvae (blood worms). There were no bottom fish because the water was fresh and the bottom salt, so no aquatics available for the oviposition.

5.10.9 Other arthropods

Swarm of butterflies the author saw near Palo Alto, California in 1925. The swarm occurred in June, was about 10 miles long and consisted of *Vanessa's*, *Papilio*, *Pieris*.[112] In Java the author witnessed mass occurrence of Libellolids (*Aeshna* – like things) on the slopes of the Merapi (1936). For two hours (±30 miles) the swarm was observed.

5.10.10 Red water

See Baas Becking (1931c), *Salt and Salt Manufacture*.[113] There are many causes for red water. We name *Oscillatoria rubescens*, *Haematococcus pluvialis*, *Dunaliella salina*, red bacteria (*Micrococcus morrhuae* Klebahn, 1919), purple bacteria. It is hard to tell whether a freshwater form is meant in the Egyptian plague.

5.10.11 Flies

Shelford mentions fly plagues. In the Australian desert [in 1936] the author collected on the head of his assistant [= Dr. J. Reuter] more than 1600 flies.

5.10.12 Mosquitos

Especially in the arctic summer, are a well known recurrent nasty epidemic.

105 Reference to Baas Becking, Tolman, McMillin, Field and Hashimoto (1927). In the 1953 manuscript *Geobiology* on p. 526-528 under the heading *Silica*, Baas Becking described the diatoms research in more detail.

106 In his Inaugural Address in Utrecht University Baas Becking (1927) referred to Vernadsky's "explosions de la vie" and referred to the *Aulacodiscus kittoni* epidemy and Forti's 'Mare sporco.'

> Masses of a yellowish or greenish-brown gelatinous substance floating at the surface of the sea and at times colouring large areas are the cause of the phenomenon known as 'mare sporco.' It is especially noticeable in the Adriatic, but may occur also in many other places. It seems that these curious masses in the water have their origin at the bottom where innumerable diatoms, usually a few definite bottom living species, in certain circumstances by rapid reproduction give rise to a large amount of a gelatinous substance impregnated with much oxygen.

Forti (1906). See also *The Origin of 'Mare Sporco*, *Nature* (1932, 129, p. 660).

107 *Pelagia noctoluca* are bioluminiscent. Light is emitted in the form of flashes when the medusa is stimulated by turbulence created by waves or by ship's motion. In his Inaugural Address in Utrecht University (Baas Becking, 1927) referred to a personal observation in the Bay of Tehnantepec, that in front of the ship there was during more than two hours a mass of the light emitting medusae, he estimated their biomass as several million tons.

108 Carl Johan Joseph Ernst Wiman (1867-1944), Swedish palaeontologist. Reference not identified.

109 *Pachychilus* is the generic name of the jute snails an aquatic gastropod. Baas Becking probably referred to *Locusta migratoria*. The species name *tartarea* is obsolete.

110 More correct is I *Samuel* 6: 1-21.

111 Baas Becking referred to the Wieringermeerpolder, newly created land, developed in the 20th century by draining parts of the inland Zuiderzee. See also notes Sections 7.9.11 and 8.5 and Feekes (1936).

112 Baas Becking probably referred to *Vanessa cardui* (Lepidoptera *Nymphalidae*), *Pieris* spp (Lepidoptera *Pieridae*) and the western tiger swallowtail *Papilio rutulus*.

113 The reference is to Baas Becking (1931c).

5.10.13 Epidemiology

(Charles Nicolle *Naissance, Vie et Mort des Maladies Infectueuses*).[114]

Lotka.[115]

5.10.13.a Typhoid

[Baas Becking left this section blank.]

5.10.13.b Malaria

[Baas Becking left this section blank.]

5.10.13.c Cholera

[Baas Becking left this section blank.]

5.10.13.d Influenza

[Baas Becking left this section blank.]

5.10.13.e Plant diseases

[Baas Becking left this section blank.]

5.10.13.f Specific malice

[Baas Becking left this section blank.]

5.10.13.g Mass death ("explosion mortelle")[116]

The four horsemen of the Apocalypse (Rev. 6) famine, war, epidemics, deaths.

Suicide (lemmings).

Swarming of termites, drought, euxenic phenomena.

F. Trusheim, Massentot v. Insekten. *Natur u Museum*, 59, 55 (1929).

Chiefly *Lochmaea suturalis* Thomas, yellow leaf beetle 2-V-29 Wilhelmshafen [tidal] worms towards dunes then out, cooler, man death 3000 litre, 40 × 10^6 beetles.

C. Wiman, *Palaeont. Zeits.*, 1, 150 (1914), 150. Dutch steamer in 1899, 33. Locusts Red Sea through counts (2-300/m^2. D… Pieris, Lüden. Melvl… tha. V. Freyberg *Naturw.*, 15, 13 (1926), Mar Chiquita [Argentina] grasshoppers as salt sea ½ × 15 cm ridge (like Artemia eggs). Dr. Gy Eberle. Ein Massensterben v[on] Heringen, … plant poisonous gas, March 15-16, 1927, Lübeck-Travemunde. *Natur u Museum* 59, 64 (1929).[117]

5.10.14 Milieu chart

Summarising we might schematise the influences milieu factors by selecting a number of them (Table 5.3a) and classifying the organisms accordingly (Table 5.3b). The relation to the organisms is given as follows:

Table 5.3a Scheme with milieu factors that influence organisms.

C	Faculty to conceive CO_2	c	Lack of the faculty
E	May live without ergones	e	Cannot do so
P	Makes use of light	p	Is unable to utilise light
A	Lives aerobically	a	Anaerobically
T	Lives at high temperatures	t	Is non-thermophilic
H	Is osmophilic or halophilic	h	Lacks this faculty
N	Is able to reduce nitrogen	n	Is unable to do so
S	Is able to reduce sulphate	s	Is unable to do so
O	May live without organic caloric food	o	Is heterotrophic
Ac	Is acidophilic	ac	Basiphilic

Table 5.3b The relation of milieu factors and various organisms: ± means eurybiotic; + or – stenobiontic.

#	Organism	C	E	P	A	T	H	N	S	O	Ac
1	Purple sulphur bacteria	±	?	+	-	±	±	-	-	±	-
2	Bluegreen algae	±	±	±	±	±	±	±	-	±	±
3	Euglena	±	±	±	±	±	±	-	-	±	±
4	*Dunaliella* (polyblepharid)	+	?	+	+	±	±	-	-	+	-
5	Sulphate reducing bacteria	±	?	-	-	±	±	-	+	±	±
6	*Azotobacter*	-	?	-	+	-	-	+	-	-	-
7	*Closteridium pasteurianum*	-	?	=	=	=	=	+	-	-	-
8	*Radiobacter Beijerinckii*	-	+	-	+	-	-	+	-	-	-
9	*Thiobacillus thiooxidans*	+	-	-	+	±	±	-	-	-	+
10	*Protococcus* from Lichens	+	+	+	+	±	?	-	-	+	±
11	Anaerobic methane bacteria of Benker	+	+	-	-	-	-	-	-	±	-
12	Diatoms	+	+	+	+	±	±	-	-	-	±
13	*Sarcina ventriculis*	-	?	-	-	+	-	-	-	+	+

Of course, the requirements could be further refined, until finally a recipe book for the mass culture of organisms should result. However, this is outside the scope of this essay.

114 Baas Becking inserted this reference to Charles Jules Henry Nicolle (1886-1936), French bacteriologist, winner Nobel Prize in Medicine (1928) for his identification of lice as the transmitter of epidemic typhus. In the 1953 version of *Geobiology* (p. 124) he referred, this time not only with a reference to Nicolle's *Naissance*, but also with a quote. The reference to Nicolle is preceded by a personal note on Baas Becking's experience in the Siegburg prisoner camp in February-May 1945:

> Symbiotic relations between two and more organisms, extensively studied in epidemiology (*e.g.*, Ross' malaria equations) often give rise to a temporary preponderance of one or two components. The author has witnessed in a German prison camp (January-May 1945) where the explosive nature of the Rickettsia infection was clearly indicated (B.B., 1945). Several months before the outbreak the infestation with body lice was almost complete. […]. The onset of the disease was but little steeper than its decline. The epidemic disappeared in the spring apparently more or less independent of the modern hygiene and prophylactic measures of our American liberators!
>
> Nicolle, a Nobel Laureate (because of his fundamental work on typhus epidemics) has described the explosive nature of such calamities in his classic *Naissance, Vie et Mort des Maladies Infectieuses*. He states (p. 82) "lorsque les propriétés virulents de certains microbes pathogènes sont portées à un point extrême en que la contamination se trouve favorisée par de grandes facilites de contact, mieux encore si ces deux conditions se rencontrent à la fois, les maladies peuvent frapper dans un temps très court un grand nombre d'individus appartenant à la même espèce. Il y a alors épidémie."

The social implications of such an outbreak are vividly portrayed by Camus (1947) [*La Peste*] in his description of a plague epidemic in Africa. The quote is on p. 82-83 in Charles Nicolle (1930), *Naissance, Vie et Mort des Maladies Infectieuses*.

The reference to 'BB, 1945' is to L.G.M. Baas Becking, editor. *The Typhus Epidemic at Siegburg Penitentiary in 1945*. Siegburg April/May 1945. Baas Becking wrote in the period April 10, 1944 until May 23, 1944 a report about the typhus epidemic in the Siegburg prisoner camp during the time he and the former prisoners were in quarantine. There is also a report of the German physician Jacob Ahles about the epidemics written in 1946 in German. Ahles (1946), *Die Fleckfieberepidemie im Zuchthaus Siegburg im ersten Halbjahr 1945*. March 1946. See NIOD 250c, nr. 167; NIOD 250c, nr. 57.

115 Baas Becking referred to Chapter VIII of A. Lotka (1924), where several examples of equations used in the epidemiology of malaria and parasitology are discussed on p. 79-99.

116 This section on mass death consists of short notes on sources that have not been developed by Baas Becking into a text.

117 Apparently references from a 1929 copy of *Natur Und Museum* from the Senckenberg Institute. Baas Becking possibly had a copy in the Utrecht prison.

5.11 Water

5.11.1 Introduction

Hippocrates in his classic *From the Water and the Places*, calls attention to this substance as milieu factor for our living beings: Man. To describe the role of water as a milieu factor would be the same as to write a textbook of physiology, as water enters into metabolism. In this section, however, we only point out a few instances in which water plays a role, such as situations in which water may become "limiting factor." (Drought, frost, physiological drought, tidal exposure, atmospheric plants) as well as the influence of water upon the shape of organisms, the morphogenetic role of water. Atmospheric moisture, particularly in connection with temperature, has a profound influence on animals, particularly mammals, as shown in Section 5.4.5 for man and sheep.

5.11.2 Drought and frost

Have, in their effects, much in common. In both cases water is removed from the cell and the cell solution becomes much more concentrated. "Gefreien and Erfrieren" [Freeing and freezing] (Molisch).

"Wilting coefficient."[118]

5.11.3 Tidal exposure

Dr. J. Zonneveld, from our laboratory (1934).[119]

Fucus platycarpus.

Fucus serratus.

Fucus vesiculosus.

Ascophyllum nodosum.

5.11.4 Intake of water vapour

Walter (*Der Hydratur der Pflanze*),[120] has given a table in which the vapour pressure is given together with the osmotic pressure corresponding. A saturated salt solution lowers the vapour pressure to 85 %, this should be about the limit (tables). MacDougal (1924) and Peirce (1901) have called attention to the redwood *Sequoia sempervirens* which in California, occurs in the so called "fog chamber", valleys in which the fog is drawn inland.[121] As a matter of fact, sequoia absorbs water vapour by the leaves, and, maybe there are a great many other plants that do so, only literature is controversy.

Atriplex vesicaria, a chenopodiaceous plant from S. Australia (J. Wood), possesses a perfect root system which it only can use a few weeks in the raining season. The rest of the year it takes up water as vapour by the leaves and Wood obtained values here far above those of Walter and corresponding to swelling pressure of ±1000 atmosphere as the leaves were able to absorb water when the saturation was only 65 %![122]

Trentepohlia (Renner). Especially in Java there are a great many species of the beautiful epiphytic or epilithic alga. On the whole, they are unable to take up water vapour when the atmosphere shows less than 85 % saturation. It is a mooted question whether contact with liquid with similar vapour tension creates comparable conditions. It is remarkable that a salt alga *Lochmiopsis* seems closely allied to *Trentepohlia* and that also the polyblepharid alga *Dunaliella* may be a fixed unicellular stage of one (or either) of them (Walter).[123] Also, dunalisation [?] occurs in both forms (see Section 7.6.7).

Certain *Lichens* are able to form where hardly ever liquid water, either dew, or rain, may be found. They apparently are able to absorb water vapour. Goebel has called attention to the enlarged hyphae of the fungeous component (Quellhyphae) which should act as a water absorbing tissue. Quispel however, experimenting with lichens proved that the fungus component did not act as a water reservoir or a water absorbing component.[124]

5.11.5 Morphogenetic influence of water

Higher aquatics …

5.12 Oxido Reduction, Oxygen, Summary

The redox potential, against a normal H_2 electrode is:[125]

$$E = \frac{RT}{N} \ln \frac{ox}{red} - F$$

(Table of dyes and substances, work of Elena on redox of surroundings).

Oxidation is:

1) addition of oxygen $2H_2 + O_2 = 2H_2O$

2) removal of electrons Fe^{2+}- (e) = Fe^{3+}

3) removal of hydrogen $H_2X + Y = H_2Y + X$

Two pages are too short even to mention the multitude of questions which arise here. In Section 5.12.4, where the oxygen balance is dealt with, the problem will be treated more fully.

5.12.1 Anaerobiosis, aerobiosis

Pasteur has aptly said "la fermentation, c'est la vie sans air." Anaerobiosis gives air to fermentation. The products of catabolic aerobiosis are only CO_2 and H_2O, while, in fermentation a whole spectrum of substances may be found. Therefore, in a meristem or at the places where differentiation occurs, the oxygen tension should not be too

118 Wilting coefficient is the level of soil moisture at which water becomes unavailable to plants and permanent wilting ensues.

119 Dr. J. Zonneveld, not identified. He must not be confused with the Wageningen Professor in Landscape Ecology Isaak Samuel ('Ies') Zonneveld (1924-2017), who started his research of the soil and vegetation in the Biesbosch tidal area in 1943 during WW II.

120 Reference to Walter (1931).

121 Baas Becking referred to MacDougal (1924) and to Peirce (1901).
For fog interception by mature coast redwood *Sequoia sempervirens* trees see Simonin, Santiago and Dawson (2009).

122 Reference to Wood (1925).

123 For Heinrich Walter see Sections 1.2 and 5.10.4.

124 Baas Becking referred to the dissertation of A. Quispel (1943, 1946) in which the findings of K.I. von Goebel on the water relations of the lichen thallus were discussed. According to Goebel the fungus protects the alga against desiccation by its water reserve in the "Quellhyphen." It appeared from Quispel's experiments (p. 522):

> […] that this protection against desiccation could only be observed at a low degree of desiccation of the thallus. On the contrary it appeared that in consequence of the symbiosis the algae are much more dependent of liquid water than had been the case in a free living state. The presence of this water reservoir in the hyphae will be only of minor importance for the gonidia and certainly the benefit will be much too insignificant to base a mutualistic theory of the symbiosis upon.

See Goebel (1926a), Goebel (1926b), Goebel (1927).

125 Baas Becking probably means the reduction potential of oxidising agent and reducing agent , which has the reduction potential V = 0.

high (Ruhland) lest the costly metabolites oxidise too far. Maybe that buds in which differentiation takes place often a year before budding (Suringar), are for this reason often protected by wax, resin, and involucrated bracts.[126] It is remarkable that the analogue of the two chief animal oxygen carriers, the iron containing haemoglobin and the copper-containing haemocyanin, to wit the Fe-containing peroxydes and Cu-containing polyphenoloxydes, occur copiously in plants, in which play other with regulation and mediation like the diënoles, they regulate the oxygen transfer to the substrate. We should not forget, however, that, apparently, biochemistry is not much concerned with oxygen. Hydrogen being the chief component in organic compounds. The oxygen comes in as a sort of afterthought. It may be (see Section 6.4.2.a) that oxygen is really an evolutionary afterthought and that many organisms that once throve upon this earth (*Equisetes*, *Lycopods*), all organisms with open and unprotected vegetation points are really suffering nowadays from a sort of surfeit of oxygen. For many anaerobic bacteria oxygen is an active poison, which cannot be withstood in the vegetative state. Transfers of anaerobes should be made, therefore, under special precautions.

5.12.2 Senckenbergiana

Senkenbergiana 14, 1932, Franz Hecht, *Der Chemische Einfluss Organischer Zersetzungsstoffe auf das Benthos* [dargestelt an Untersuchungen mit marinen Polychaeten, insbesonderes *Agricola marina* L.], p. 199-220 *Arenicola* may live in high H_2S without oxygen.[127] *Nereis* even better. Dissociation curve, Barcroft and Barcroft, *The Blood Pigment of Arenicola*. *Proc. Roy Soc*. 96, 192 (1924).[128]

[Baas Becking inserted Fig. 5.25, from Barcroft and Barcroft (1924, p. 36).]

"The difference seems to accord with the differences of function of the haemoglobin in the two forms of life".[129] In the higher mammals its duty is to discharge a large quantity of oxygen whilst traversing a capillary in a few seconds of time, in *Arenicola* the object of the haemoglobin is evidently to return or store oxygen on which the organism can draw back when it is sealed up in its hole at low water.

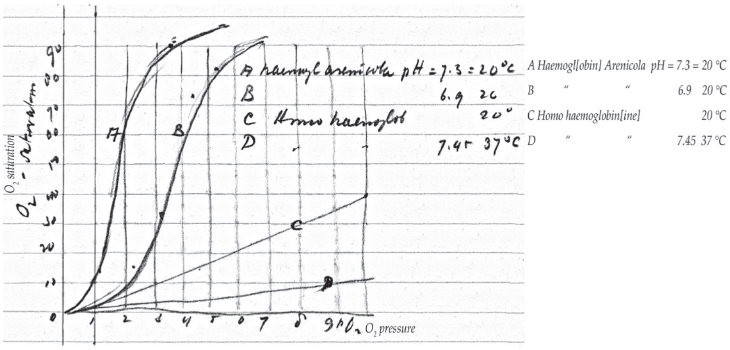


Figure 5.25 The relationship between saturation (in %) with oxygen (y axis) and pressure of oxygen (x axis in mms) of haematoglobin; A. *Arenicola* pH = 7.3 at 20 °C; *Arenicola* pH 6.9 at 20 °C; C. Human blood pH = 7.45 at 20 °C; Human blood pH = 7.45 at 37 °C. After Barcroft and Barcroft (1924).

Milieu study Hecht proves that decomposition benthos may create anaerobic conditions as well. At low water *Arenicola* usually plenty oxygen. Aerobic lives on its glycogen. The principle of Barcroft might be extended to other respiratory pigments, such as haemocyanin. Plants may grow with their roots in the black mud, stone, like the willow (Cannon) probably transport oxygen chemically. Others transport it directly, as in rice (van Raalte) when it is even excreted.[130]

5.12.3 Euxinic phenomena ("Verjauchzung") [= Putrefaction]

A disturbed cycle, where, apart from an almost complete exhaustion of oxygen, the H_2S tension is high (Black Sea as example, Walfish Bay).[131] H_2S is toxic as such, in highly alkaline solutions, where chiefly SH^- and S^{2-} occurs, it is much less harmful. This is perhaps the reason why purple bacteria, that live on H_2S and its dissociation products, only occur at high pH. The significance of an ocean "sill", see Hardon, Kuenen, Snellius expedition.[132]

126 The reference to Suringar about 'budding' not identified. Baas Becking referred to Willem Frederik Reiner Suringar (1832-1898), Dutch botanist, Professor of Botany and director Hortus Botanicus Leiden University (1862-1898) and director Rijksherbarium Leiden (1871-1898). His son was Jan Valckenier Suringar (1864-1932), from 1900 till his death in 1932 director Wageningen Botanical Garden. Baas Becking's cousin Louise Hermine Baas Becking (1881-1969) was assistant of Valckenier Suringar until her marriage with F.A. Moraux in 1921. She was responsible for the design of the Wageningen Botanical Garden De Dreijen ('Baas Beckingtuin').
Baas Becking wrote a well informed outline of the scientific work of W.F.R. Suringar, his predecessor in Leiden. See Veendorp and Baas Becking (1938, p.170-177).

127 According to Hecht (1933) the influence of H_2S, a product of decomposition of organisms, on the benthos has been overestimated. He found that *Arenicola* and *Nereis* were not affected by a temporary content of hydrogen sulphide in the water. He also called attention to the fact that, even if hydrogen sulphide is found in the sediment, as is indicated in fossil sediments by the occurrence of pyrite, we cannot definitely conclude that it was present in the water, and only the quantity present in the water influences the benthos.

128 Barcroft and Barcroft (1924, p. 41-42) owed that the red blood of *Arenicola* contains a form of haemoglobin different from that contained in human blood. The oxygen dissociation curve shows a higher affinity for oxygen, so that the gaseous exchange takes place at very low pressures. The blood volume of *Arenicola* varies greatly in different worms, but the oxygen capacity is much more constant, being of the order of 0.01 cc of O_2 *per* g of worm. This quantity is definitely less than the maximum the *Arenicola* is estimated to need during the time when its hole is sealed up at low water. Nevertheless, it is so nearly of the same order as to make clear the probable function of the pigment, namely, to act as a reserve store which the organism can use up when it has not access to seawater.

129 Quote from Barcroft and Barcroft (1924, p. 36).

130 Reference to Maurits Henri van Raalte (1907-2002), plant physiologist at Treub Laboratory Buitenzorg (1939-1956), later Professor of Plant Physiology, Groningen University. See van Raalte (1941).

131 In the 1953 manuscript of *Geobiology* (Baas Becking, 1953a, p. 492) Baas Becking referred to:

> Brongersma-Sanders (1943) has called attention to the mass death of fish and molluscs, which occurs periodically in an area of Walfish Bay, South Africa. Here sediments rich in FeS and in organic matter are found which are apparently, apart from bacteria, deprived of life. She ascribes this mass death to a water bloom of a Dinoflagellate. These organisms are reputedly toxic to fish and are the cause of similar calamities in other regions of the world. Sulphate reduction and the subsequent exhaustion of the water in oxygen might be a secondary phenomenon.

See Brongersma-Sanders (1943 and 1957).

132 Reference to the Snellius expedition, an oceanographic survey of the waters of eastern Indonesia from July 1929 until November 1930. H.J. Hardon, Ph. Kuenen and H. Bosma were participants of the expedition, the scientific results were published by Brill. The sea voyage was led by lieutenant F. Pinke, brother of Baas Becking's sister in law Eliza Hendrika Pinke (1898-1942).
'Ocean sill' is a sea floor barrier of relatively shallow depth restricting water movements between ocean basins.

5.12.4 Processes which influence the terrestrial oxygen balance

[Explanation of numbering in Table 5.4.]

1) Plankton = 5 ton/Ha, vegetation to 30 ton Ha. Average over earth surface ±10 tons/Ha of which ±30 % carbohydrate, (*per* annum). 2 ton carbohydrate has liberated out of CO_2 2.4 ton of oxygen/Ha. 1 Ha = 10^8 cm², 1 ton = 10^9 mg, 24 mg/cm² oxygen.
4) According to Clarke (1916) 300 × 10^6 tons of sulphate disappear into the ocean. They should be reduced. This would make available, for other oxidation 200 × 10^6 tons of oxygen.
5) Similar order of magnitude.
8) A fraction of 4). Total R_2O_2 to be reduced only 75 × 10^6 tons.
9) In combustion of coal and oil (±3800 × 10^6 ton). 4000 x 10^6 ton of oxygen are absorbed corresponding to 2 mg/km² of the earth's surface.

Now everything is uncertain, except the order of magnitude *per* m² there is 7.5 kg C (Neale from Clarke, 1916) in atmosphere *per* cm² 115 g C and 300 g O_2. Despite the analyses of Goldschmidt, we are very far yet from the construction of a reliable oxygen balance (see Fig. 5.26 and Table 5.5). The humus (50 % C, over 1/3 earth surface 1 %) would amount to 330 mg/cm² carbon (for a layer 1 metre deep). If annual accretion would amount to 1 % of this amount 3 mg/cm² carbon would be shielded from oxidation or a sum of 8 mg/cm². Man consumes on the average ≙ 2000 cal = 3 × 676 cal = 3 × 6 x 32 g O_2 = 576 g O_2. There are 2 × 10^9 of the species 1.15 × 10^{15} mg N *per* cm² 5 × 10^{14} mg. Oxygen.

Table 5.4 Processes which influence the terrestrial oxygen balance.

Processes which influence the terrestrial oxygen balance		
Photosynthesis	$CO_2 + 2H_2O \rightarrow HCOH + H_2O + O_2$ (green plant)	1
	$CO_2 + 2H_2S \rightarrow HCOH + H_2O + 2S$ (purple bact.)	2
	$CO_2 + 2H_2S + 8H_2O \rightarrow HCOH + X$ (purple bact.)	3
Chemosynthese	$SO_4^{2-} + CO_2 + H_2X + H_2O \rightarrow S^{2-} + HCOH + X$ (sulphate reducers)	4
	$S + 4H_2O + 2CO_2 = SO_4^{2-} + 2HCOH + 2H_2O$ (inorgoxidants)	5
Caramelisation	$C_6H_{10}O_5 \rightarrow 6C + 5H_2O$ (caramelisation)	6
Paraffinisation	$C + 2H_2 \rightarrow CH_4$ (paraffinisation)	7
Iron oxidation	$Fe(OH)_2 + 2H_2O + O_2 = Fe(OH)_3 \rightarrow Fe^{2+}$	8
Respiration	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	9

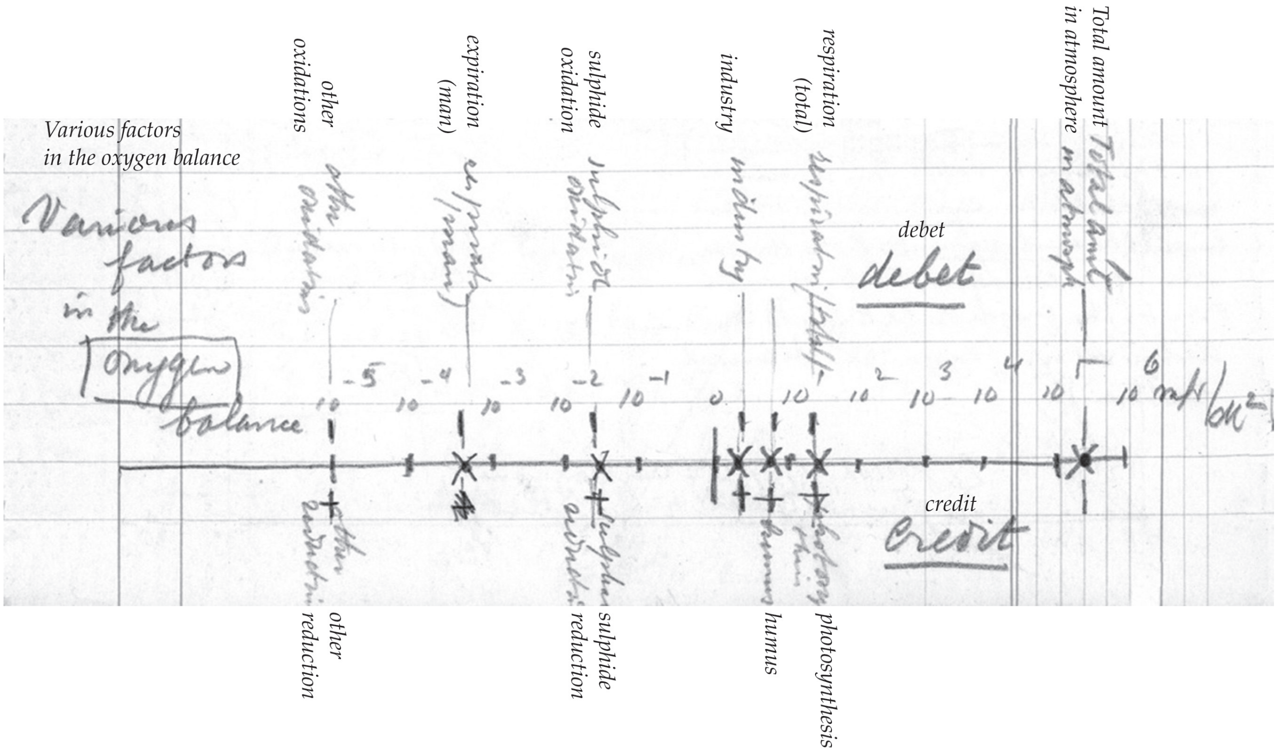


Figure 5.26 Various factors in the oxygen balance in mg oxygen/cm²/ year. Credit in balance: Photosynthesis; Humus; Sulphur reduction; Other reductions. Debit in balance: Total amount in atmosphere; Respiration; Sulphide oxidation; Expiration (man); Other oxidations.

Table 5.5 Quantitative data on the oxygen balance in $mg/cm^2/year$.

Credit in $mg/cm^2/yr$		Debit in $mg/cm^2/yr$	
Photosynthesis	24	Respiration	24
Chemosynthesis (?)	0.000001	Industry	2
Saved in humus	8*	$Fe^{2+} \rightarrow Fe^{3+}$ Sulphide and sulphur oxidation	6*
Saved in sulphate reduction	0.04		
Saved in other reductions (?)	0.000001	Other oxidations (?)	0.000001
* this may be too high	32 mg/cm^2		mg/cm^2

Now of the total 300 g O_2/cm^2 (not 230 g, as Goldschmidt calculates from *volume* % instead of weight %) 10 % enters into the cycle of matter, less than 1 % is due to human activity. Goldschmidt ascribes a very important role to the oxidation of inorganic compounds (weathering of Fe^{2+}, of sulphides, of sulphur *etc*.). Except respiration the only other factor of importance that enter in are 1) the carbon in the humus, and 2) this oxidation of inorganic compounds, of course. The credit side has to be little higher than the debit, the gain, figuring on 1000 x 10^6 years to accumulate 3 x 10^5 mg O_2/cm^2, would 0.0003 mg O_2/cm^2 of the same order of magnitude as the total respiration of mankind.

5.13 Summary

The milieu represents a finely balanced set of conditions which, when upset may cause a profound influence upon the vitality, whether in a positive or in a negative sense, of the organism. Most organisms are entirely and passively a prey of the milieu, only in some cases there are regulatory functions (heat regulation; see Section 4.2.5.b). In many instances there is a very narrow relation between organisms and environment, there is a marked *resonance* of the living being and “le monde ambiant.” Changes in the life cycle, as we shall see, are often caused by changes in the outer world, whether diurnal or seasonal, or both. These influences are super imposed upon those of the internal milieu.

6. INFLUENCE OF ORGANISMS

6.1 Concentration and Dissipation

6.1.1 Concept

From Lavoisier (1790) we owe the rule of the indestructability of matter: "rien ne se perd, rien ne se crée". Robert Mayer (1842) has created its analogue in energetics: the rule of the indestructibility of energy, "das Gesetz der Erhältung der Kraft". Both rules have become to one since Einstein's demonstration of the identity of matter and energy.

Now Clausius formulated the second law of thermodynamics in 1855. This law states that the diffuse form of heat, the entropy interacts at the expense of the useful work performed during any energy transaction. Bolzmann recognises this increase of entropy as a general trend in nature and predicts a "Wärmetod" for the Kosmos.[1]

We are interested in the material counterpart of the second law of thermodynamics. Analogous to an increase in diffuse, non-utilisable energy, the entropy, there should be, during a chemical or mechanical reaction an increase in the material dispersion of the system. This material dispersion we call *dissipation*. At another place in this book, we shall revert to this problem (see Baas Becking, *Proc. Roy. Ac.*, 1942 and Burgers, *Entropie en Levensverschijnselen, Verh. Ak.*, 1943) when we deal with the influence of forces both animate and intelligent.[2] The workings of man as shaper of the environment. Here it should suffice to state the influence of organisms upon the dissipation. Organisms are able to concentrate (geochemically) rare elements. Organisms are also able to exclude chemical compounds from their internal milieu. But the effect of the element upon the organism does not need to go parallel to its concentration. Now in squandering our heritage we have sown that which we cannot harvest. We have dissipated, minutely dispersed, a number of elements, that actually belong in earth's molten core, or in the calx surrounding it. We owe it to living things that these are brought back to us *concentrated* by the anti-dissipatory action of living matter. Of course, care should be taken not to squander at a rate greater than accumulation and concentration. And the squandering may be not only our doing, and the concentration not only a biological process, at that. Thus, both animate and inanimate seem to collaborate here.[3]

6.1.2 Les éléments concentrateurs

(Baas Becking, 1942a; see also Noddack, 1942, *Naturwiss.*),[4] V.M. Goldschmidt (1923).

When we plot the log concentration of the bioelement within in the organism against the logarithm of the concentration of these elements in the earth crust, we find little correlation (Fig. 6.1). If we plot against the concentration in the hydrosphere, we see only 2 elements, hydrogen and oxygen on the diagonal, they are neither concentrated or dissipated. This is rather evident, in as much as organisms consist for such a large part of water. But the organism has apparently created its own world, and the composition of this world, is quite different from that of its surroundings. We have seen in Section 1 how preponderant the elements O, Al, Fe, Si are, still, the organism has to build something quite different, at least quantitatively different.

6.1.2.a Carbon

Carbon is, of course, preponderant, it has to be concentrated from 0.002% in the hydrosphere to ±10% in living matter! This concentration is brought about by the carbon dioxide assimilation of the green plant and the subsequent dehydration of the glucose formed to products as cellulose. The dissipation of the carbon is never so great as the concentration, or part of it, formerly was.

6.1.2.b Iron

Iron is, in seawater only present in a few γ/cm^2 (as Cooper (1935) showed), as the fluoride.[5] How the intake and concentration take place we do not know. Inorganic iron is present in plants (Molisch). Most of it is bound to porphines and the like. The re-dissipation is presumably complete.

6.1.2.c Iodine

The most interesting case of concentration we find in the iodine. In freshwater it is hardly present. Still all organisms contain it, and some (mammals, sponges, algae) in appreciable quantities. We only know it in organic compounds with the organisms, such as di-iodothyrosines or thyroxine (Bayer) [small drawing of the molecule structure]

---

1 The heat death of the universe (also known as the Big Chill or Big Freeze) is a theory on the ultimate fate of the universe, which suggests the universe would evolve to a state of no thermodynamic free energy and would therefore be unable to sustain processes that increase entropy. The concept was first proposed in loose terms by Lord Kelvin in 1850. See also Baas Becking (1946b, especially p. 30).

2 Reference to Baas Becking (1942a) and Burgers (1943).

3 In the 1953 version of *Geobiology* Baas Becking summarised the concept of 'dissipation' as follows (p. 513):

> Organisms concentrate and accumulate various elements, but after their death these elements enter the cycle and they may be reconverted into a series of other organisms. Some of the elements are side tracked and immobilised. Organisms are, on the whole, accumulators of matter. We should not forget, however, that, in material transactions as well as in energy transactions, irreversibility enters in. There is, in a way, a material analogue of entropy, which we shall call dissipation (Baas Becking, 1942a and 1946b). A gold nugget represents a high concentration, and therefore a low dissipation of the element Au, but if this nugget be dissolved in aqua regia, the dissipation is proportional to the amount of solvent. If we pour this solution into the ocean, the gold is, to all intents and purposes, completely dissipated and we cannot, as yet, by economic means accumulate it again, However, dissipation is less merciless than entropy in that it always leaves room for hope. It may be possible, in the future, to find a process by which gold will be extracted from seawater (Haber). Dissipation is, moreover, not always accompanied by a decrease in the energy level, as is the case in the example mentioned above, where the work, necessary to reconcentrate the gold, may be calculated from the Nernst equation. The subdivision of a large drop into small drops, while dissipatory in nature, requires energy, and also the change or water from the liquid into the gaseous state.
>
> Dissipatory processes play a large role in human economy. Mining, for example involves both decreases and increases in dissipation, First the ore is gathered, with a concomitant decrease in dissipation. This decrease is even steeper when the metal (*e.g.*, iron) is separated from the ore. But now this metal is made into bars or ingots and distributed. The dissipation will increase, and this increase will be very steep when tin cans are thrown away, or iron conduits corrode with rust. While much metal may be (and actually is) regenerated, quite a large fraction becomes irreversibly dissipated. This means that we cannot, by known technological and mineralogical processes retrieve it.
>
> Modern economics actually promoted dissipation and it often prefers perishables to articles of lasting value, in as much as the latter will prevent speedy expansion of business.

4 Reference to Baas Becking (1942a), Figure 1, which also has a table with the relative concentration of elements in the cosmos. and in the lithosphere of the earth. Walter Noddack (1893-1960) and Ida Noddack-Tacke, German chemists and physicists. Possibly a reference to Noddack (1942).

5 See also Section 3.8.12.

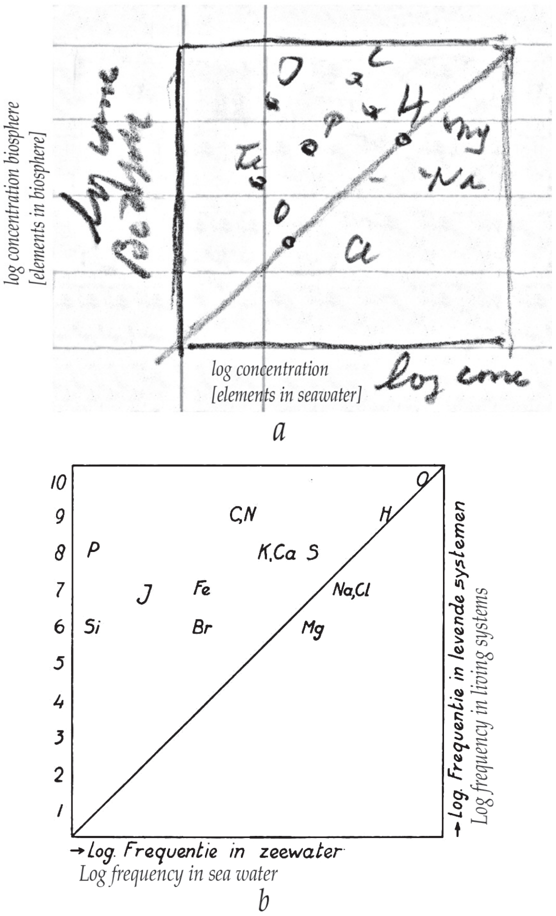


Figure 6.1 **(a)** Rough sketch of relationship between (log) frequency of elements in living organisms and (log) frequency of these elements in seawater. **(b)** Figure 2 in Baas Becking (1942a). (X-axis) (Log) frequency in seawater. (y-axis) (Log) frequency in living systems.

6.1.2.d Phosphorus

In freshwater and in seawater a veritable minimum factor. Enters the plant as acid phosphate ion (v.d. Honert),[6] and is built in in various compounds (lecithinoids, Cu phosphate and apatite). It cannot be induced by living cells, although there are, perhaps, bacteria that may perform this feat.

6.1.2.e Fluorine

Toxic when present in more than a few γ/cm^2 in the milieu. Enormously concentrated and built in the structure of bone and tooth, in the marine organisms more than in land inhabiting organisms. Its influence in plants to most well known.

6.1.3 Les éléments dissipateurs

The inspection of the mineral analysis of ore, or a few groups of organisms, is never sufficient to obtain an idea about the significance of such minerals. Notably this is the case with Na and Cl. We know that they are useful things in the external milieu, as sodium and the most abundant of the earth alkalis, such as Ca and Mg. We know that the formation of HCl plays a role in the digestion in higher animals, and that NaCl is a regular component of the body fluids. Also, its decrease goes parallel with certain pathological phenomenon. Still, NaCl causes in plants curious aberrations (succulence) which are induced hereditarily on certain species, but make us suspect that the role of Na and Cl is not as universal as we thought before.

6.1.3.a Sodium

There is a tenfold decrease at least from seawater concentrations to body fluid. As Kuenen has shown even halophyte organisms like *Artemia* have quite diluted body fluids.[7] Ancel Keys demonstrated the presence of a NaCl secretory gland in the cell.[8] Kidney function also performs work to concentrate excretion NaCl and so to dissipate it (Nernst RT log C_1/C_2).

6.1.3.b Magnesium

In organisms, in certain enzymes, in chlorophyll, and in the aleurone protein. Necessary apparently in very small quantities, while present in seawater in high concentrations. The method of dissipation is totally unknown. How its permeation as against the necessary Ca is regulated, remains a mystery.

6.1.3.c Chloride

Excretion of chlorides is known to occur in succulents, as well as in other plant families. This should elaborate the statement made above under sodium. Its position in the Hofmeister (1888) series, (or better, lyotropic permeability series) might account for its lack of accumulation within the cell.[9]

6.1.3.d The position of hydrogen and oxygen

Although hydrogen and oxygen are intensely used in the cell, the amount of these elements taken up in metabolic activity is so small as compared with the total amount of cellular water that it may conveniently be neglected. Even all of the hydrogen and oxygen fixed in organic compounds is out small percentage of the total cell weight.

6.1.4 Summary and conclusions

A plant may grow, constantly accumulating and concentrating atmospheric carbon (Fig. 6.2). It grows from *I* to *M*, and the dissipation of the carbon decreases, perhaps following some such curve as given in the diagram. At *M* it dies and decays or is eaten, the dissipation of its carbon increases, but never to the level as where it comes from. There is a gain, a net gain in concentration, incarcerated in the bodies of the organisms which fed upon the original plant and also incorporated in fossilising carbonaceous material. In the cycle of the carbon there is no complete repetition, part of it is held back. In the case of the iodine, we meet the same thing, although the factor 'fossilification' is absent. But still the concentration in an original organism *I-M* may partly be maintained by organisms feeding upon this initial organism (level *c* in the figure). The 'fossil' concentration becomes again quite important in such elements as phosphorus while in others, like nitrogen, it is neglectable (only Chilean nitrate and guano).

6 Taco van den Honert (1899-1959), Dutch botanist. In the 1940 he became deputy director of 's Lands Plantentuin in Buitenzorg, in the absence of Baas Becking. In December 1945, he was successor of Baas Becking as Professor of General Botany in Leiden. Baas Becking probably referred to van den Honert (1932), *On the Mechanism of the Transport of the Organic Materials in Plants.*

7 Reference to Donald Johan Kuenen (1912-1995). Kuenen was a pupil of Baas Becking. In 1939 he defended his PhD thesis in Leiden *Systematical and Physiological Notes on the Brine Shrimp* Artemia. Because Baas Becking was at that time in Indonesia, Hilbrand Boschma was his PhD advisor.

8 Reference to Ancel Keys (1904-2004), American physiologist. Baas Becking referred to Keys and Willmer (1932), Keys (1933).

9 Baas Becking referred to Hofmeister (1888), who described the lyotropic series that defines the salting in/salting out effect of different ions ($F^- > SO_4^{2-} > HPO_4^{2-} > Cl^- > NO_3^- > Br^- > ClO_3^- > I^- > ClO_4^-$; $NH_4^+ > K^+ > Na^+ > Mg^{2+} > Ca^{2+}$). See Oren (2011, p. 13).

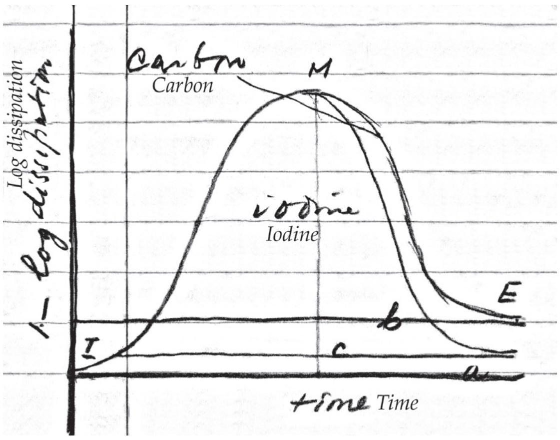


Figure 6.2 Dissipation of carbon and iodine (in 1-log dissipation) during the life cycle of a growing plant.

It would be interesting and worthwhile to investigate in detail the concentration and dissipation of a number of bioelements. As we shall see later, 'waste' is one of our chief problems. The concept of dissipation is closely allied to this problem. In this section we shall further deal with the influence of organisms upon the inanimate world. It will be seen that the influence is profound and in certain cases, as in the atmosphere, dictatorial. Biochemically, this influence may be ultimately traced to the accumulation, the concentration power of the living cell. To elaborate upon the mechanism of this concentration, intrability and permeability in general, is a task for physiology and being outside the scope of this essay.

6.2 Periodic Changes in the Physical Milieu

6.2.1 Introduction

People in a crowded room not only change the CO_2 tension, but also the temperature and the vapour pressure. Soon we are right outside the 'area of well being' and we become too dazed even to speculate upon the influence of organisms upon the physical milieu. We are struck, when aboard a steamer, or walking along the beach, or in the forest, by the wonderful phenomena of bioluminescence. From the example given it would appear that organisms exert a marked influence upon the physical milieu. But this influence is local, and, what is more important goes with very little energy exchange. The biophysical phenomena, while curious, lack the great geological importance which is particular to many other biological phenomena.

6.2.2 Heat production

Description of the wonderful thermostat which is the warm blooded animal, falls outside the scope of this essay. Animals with imperfect eurythermy (duck bill, insectivores, bats and rodents) show real hibernation.[10] During hibernation they are poikilothermic after awaking a bat may raise its temperature by 25 °C in less than a minute. It should be remarked, however, that even cold blooded animals may raise the temperature of the environment by several degrees. Pythons are said to incubate their eggs. The heat production by microbes is a well known phenomenon and is dealt with more fully in Section 5.4. Animals make use of this heat production! The mallard hen, *Megapodiidae*,[11] occurring in Australia and islands of the Pacific, lays her eggs in mounds made of rotting leaves. The cobra is said to do the same. About the regulation of temperature inside a beehive (see Shelford, 1929, p. 322). Higher plants may produce heat in the floral organ, raising the temperature as high as 48 °C. (*Nymphaeacea*, *Aracea*, *Aristolochiacea*). In *Sauromatum venosum* (*Aracea*), van Herk (1937) found enormous consumption of sugar under the influence of the yellow respiration enzymes.[12] Post-mortal (necrobiotic) changes in leaves (tobacco) may give rise to temperatures up to 50 °C. According to Schwarz and Laupper (1922) the self combustion of hay is due to a chemical reaction catalysed by iron. According to Mach (1900a and b) this is a (pyrophoric iron) in probably localised in the plastid.[13]

6.2.3 Light production

Certain marine bacteria (*B. phosphoreum*, *V. indicus*)[14] various *Hymenomycetae* (*Mycena*, *Xylaria*),[15] lampyrid beetles, a crustacean (*Cypridina*)[16], jellyfish, and gastropods are able to radiate a blue or green, perfectly cold light. The mechanic of this emission was first studied by R. Dubois (1886 and 1892) and later by E.N. Harvey and co-workers (1928).[17] Pierantoni (1921) claims that light emission of higher animals and worms takes place by symbiotic bacteria.[18] In the last decade the late L.S. Ornstein and A.J. Kluyver and co-workers have been able to elucidate the mechanism of light emission further.[19] Already, Dubois (1886) assumed the presence of a substance *luciferin* and atmospheric oxygen changed into

10 Eurytherm is an organism, often an endotherm, that can function at a wide range of ambient temperatures.

11 Baas Becking probably referred to the 'Malleefowl', a megapode in the family of *Megapodiidae*. It is a stocky ground dwelling bird about the size of a domestic chicken. It is notable for the large nesting mounds constructed by the males and lack of parental care after the chicken's hatch.

12 Adriaan Willem Hendrik van Herk (1904-1966). Since 1939, van Herk replaced Baas Becking in Leiden. In 1946, he became professor in Amsterdam. Baas Becking referred to van Herk (1937) *Die Chemischen Vorgänge im Sauromatumkolben.*

13 Reference to Ernst Mach (1838-1916), Austrian physicist and philosopher. Baas Becking possibly referred to Mach (1900b) *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen,* or to Mach (1900a), *Die Principien der Wärmelehre.*

14 *Photobacterium phosphoreum* Beijerinck (1888), a gram negative bioluminescent bacterium living in symbiosis with marine organisms; *Vibrio indicus* a luminescent bacterium.

15 Bioluminiscent fungus species. They emit a greenish light at a wavelength of 520-530 nm. The light emission is continuous and occurs only in living cells.

16 Vargulin, Cyprinid luciferin or *Vargula luciferin*, is the luciferin (light emitting compound) found in the ostracod *Cypridina hilgendorfii*.

17 It was the French pharmacologist Raphael-Horace Dubois (1849-1929) who first investigated the components required for the bioluminescent reaction. He established the luciferin-luciferase system in the elaterid beetle *Pyrophorus* and in the bioluminescent mollusk *Pholas dactylus*. His detailed work was summarised in two works published in 1886 and (on the mollusk) in 1892. Raphael Dubois was able to produce luminescence in the laboratory. Eventually, he named the two extracted components, calling the molecule that was consumed in the reaction "luciferine" and the enzyme responsible for the reaction was termed "luciferase." As history continues, E.N. Harvey tested various combinations of luciferase enzymes and substrates to find that both luciferases and luciferins were not interchangeable between species.

18 Umberto Pierantoni (1876-1959) demonstrated that the cells of the light organs of certain beetles and cephalopods contained luminous microorganisms that also existed in the egg and could be transmitted from generation to generation. Baas Becking referred to Pierantoni (1921). See Sapp (1994, p. 84).

19 In 1935, the Utrecht physicist Leonard Salomon Ornstein (1880-1941) started a collaboration with the Delft microbiologist Albert Jan Kluyver (1888-1956). Ornstein had received a grant from the Rockefeller Foundation to bring together a group of researchers who would be engaged in research in the field of biophysics. The 'Biophysical Group Utrecht Delft' was created under the joint leadership of Ornstein and Kluyver. The group was housed in the physical laboratory in Utrecht. Research subjects were photosynthesis in single celled green algae and purple bacteria and the bioluminescence of luminescent bacteria.
Baas Becking probably referred to Kluyver, van der Kerk and van der Burg (1942), *The effect of radiation on light emission by luminous bacteria.*

oxyluciferin. Now Kluyver has been able, by a very ingenious method, to obtain the spectrum of bacterial luciferin and to find organic, luminescent compounds, which show similar spectra (oxychinones ?).[20]

6.2.4 Electricity

50 millivolt is usually the potential drop near the other phase of a living cell. Certain specialised cells of specialised tissues of tropical fishes (electric eel, and rays [order Torpediniformes]) are able to generate currents of 40 – 60 V. About the mechanism of the process the literature is still obscure.

6.2.5 Humidity

At another place (Section 3.6.11) we shall deal with the influence of organisms upon atmospheric humidity. Where the evaporating capacity of bare soil and vegetation often greatly differ, it is obvious that organisms contribute greatly to the atmosphere and influence its humidity. The effect has, up till now, been studied little, although much speculation exists upon this, and allied matter.

6.2.6 Summary and conclusions

While the changes caused by organisms in the chemical milieu are of enormous geological importance the microbes, the plants and the animals leave no imprint upon the physical milieu. The changes here are interesting, they are measurable, they are manifold, but they are of no further geobiological consequence. Of course, the influence upon the cystic movements of water is enormous, and requires special treatment at another place.

Text box 6.1 – Baas Becking notes made prior to writing the manuscript

Loosjes and Schuffelen (1943). Roots of higher plants (oats). K intake and excretion in two sided process. Both processes of same order of magnitude. By means of radioactive K. Dependent upon concentration, activity and potential difference, peripheral root tissue and milieu.[21]

6.3 Periodic Changes in Chemical Milieu

6.3.1 Introduction

Already, Sachs (1865) could demonstrate the excretion of acids (he ascribed the action to CO_2 of plant roots, which he grew between marble slabs, with the resulting corrosion of the calcite).[22] It is known that spectacle lenses, window glass and photographic plates are attacked, in the tropics, by a silica dissolving fungus, an organism, therefore, that is able to secrete alkali. The chemical influence of organisms is manifold, and only a few instances may be mentioned.

6.3.2 Changes by photosynthesis and respiration

Respiration in an aqueous milieu, by liberation of CO_2, will acidify the water as H_2CO_3 is formed which has a dissociation constant of 4.7×10^{-7}. According to some, only part of the CO_2 forms, with H_2O, H_2CO_3. According to others the acid present is not H_2CO_3 but either a brine acid $C(OH)_4$. In any case the acid seems too weak for H_2CO_3!

Photosynthesis, by withdrawal of CO_2 will make the water more alkaline. The water, which is much buffered to the acid side, but very weakly buffered to the alkaline side will suffer, in 1 litre, a large starfish for hours without marked drop in the pH. A few fragments of the alga *Ulva*, in the light, will cause the pH to rise within a few hours from 8.1 - 9.2.

6.3.3 By recretion, excretion and secretion

In the section on metabolism many examples of the excretion of important organic compounds by plants may be given. Here we call attention to substances which may poison the milieu, for competition. We mention here the well known penicillin of Raistrick[23] and the remarkable, amine-like compound excreted by the alga *Chara* and the anti-germination substances discovered by Troschel (1854) as secreted by many seeds of economic plants. Sepia is a remarkable camouflage substance secreted by *Loligo*. [in margin: *Tonna galea*, H_2SO_4,[24] centipede, HCN, beetles, iodine!]

6.3.4 By exchange

Baumann and Gully (1910) claim the following origin for the acid in *Sphagnum* bog.[25] The bog being ombrogenic (fed by rainwater only) mineral content of the water will be low. The cations in the rainwater (mainly Na) are absorbed in the cell walls of the *Sphagnum* and exchanged for H^+. Assuming a plausible value for NaCl in rainwater, ±30 micromolar we might expect the equivalent of 0.5×10^{-3} N Na^+ in H^+ions, corresponding to a pH of 4 - 0.7 = 3.3. This may be actually a pH observed in a fen moor! Baas Becking and Nicolai (1934) and Vaas repeated the experiments under a variety of conditions and confirmed, on the whole, the above hypothesis.[26] Activity of so called humic acid (Odén, 1922), CO_2, iron salts or organic acids they were able to exclude. As the only anions in the rainwater were Cl^- and SO_4^{2-} is quantitatively reduced in a *Sphagnum* bog to H_2S the acid present should be hydrochloric acid.

Thompson, Lorah and Rigg (1927) were able to corroborate these findings for Canadian peat bogs. We shall have occasion to revert to this problem again in Section 9. Suffice is to state that agar treated with HCl to remove the Ca, and washed until neutral, will become acid again when watered with dilute NaCl (H. Bungenberg de Jong). Roots have been shown (by means of radioactive K) (Schuffelen and Loosjes, 1942 a and b) (see Section 6.3, *Periodic Changes in Chemical Milieu*), to exchange K between internal and external

20 Baas Becking's 'chinones' are Quinones, essential components of the electron transport systems of most organisms and are present in membranes of mitochondria or chloroplasts.

21 Baas Becking referred to Schuffelen and Loosjes (1942a and 1942b).

22 Reference to Sachs (1865) *Experimental-Physiologie der Pflanzen*. Julius Sachs (1832-1897), founder of experimental plant physiology.

23 The reference is to Harold Raistrick (1890-1971), British chemist who played a role in the discovery of penicillin as an early collaborator of Robert Flemming. In the early 1930s he extracted a crude form of penicillin, but was advised by senior doctors that it had no future as a medicine for humans—it was too unstable.

24 In 1853 F.H. Troschel and Johannes Müller examined in a provisional laboratory in Messina two live specimens of the Giant tun shell, *Tonna galea*. When Troschel started to break one of the shells the mollusc immediately stretched out its proboscis and squirted from its tip a jet of fluid that fell on the marble floor. Samples of the secretion were analysed and contained 3% sulphuric acid. Most tonnacean gastropods probably have the ability to secrete a fluid from their salivary glands containing free H_2SO_4.
See Bolis, Zadunaisky and Giles (1984, p. 50-54).

25 Already in the 1934 edition of *Geobiologie* Baas Becking referred to this research (Chapter VII, p. 77, English edition).

26 Reference to Baas Becking and Nicolai (1934). The experiments of K. Vaas are reported in this publication.

milieu. Both processes are of almost equal intensity. Here, apart from potential and membrane effects, metabolism plays a large role.

Arens (1934) and his pupils (Lausberg, 1935) have shown that leaves excrete large quantities of salt (leaf weight *per* season) chiefly potassium acid phosphate.[27] When the leaves (tobacco) are washed by rain these salts will become available to the plant again. The amount excreted in this way may mean more than ½ of the weight of the leaf *per* season. It is, therefore, not indifferent whether tobacco is harvested before or after rain!

Text box 6.2 – Baas Becking notes made prior to writing the manuscript

[Three pages with annotations in ink.][28]

Suborder *Actipylea* (Genera *Actinelius*, *Acanthociasma*, *Acanthometron*, *Acanthonia*, *Sphaerocapsa*, *Diploconus*) of *Radiolaria*, skeleton strontium sulphate (Kudo, Fig. 168, p. 371).[29]

Caustobiolithes, Haquébard (1943) probably autochthonous.[30] Probably autochthonous. H. Potonié (1910), carbonisation and humification (boghead and cannal form bitumunisation from sapropelite).[31] Nomenclature of Stopes:[32] *vitriet* (shining), *dunite* (matt), *fusiet* (charcoal fossil), *clarite*, *vitrite* without structure = *collite*, with structure *telite*.

(= xylinite + periblinite + subernite), fusite = fusinite.

Dunite = resinite + eximite + micrinite (fine debris).

Clarite = vitrinite + exinite (mixture of vitrite + durite?).

Vitrite conchoidal fracture = collite (colloid) + tellite = structure.

In vitrite cell lumina filled with collite, in fusite cell lumina filled with gas. Originates fusite under dryest conditions, vitrite wetter, dinite wetter, pseudo cannal still wetter. Fusite probably not formed by forest fires. (2,000 sq. metre in Pittsburg 2 layers) sometimes known from fires.

Lieske thinks fusite originates in sediment covered moor.[33] By Haquébard enorme literature.

(Potonié (1910), vitrite perhaps fossil dopplerite, due to perhaps turf detritus).

Self heating of hay, see Schwarz and Laupper (1922).[34]

Boekhout and de Vries 'carbonised' haystack! Cannot be through the agency of bacteria. Very dry hay may carbonise.[35]

Humic acid forms have antiseptic action.

1912, Maillard. Carbonisation is a purely chemical process.[36]

1922, Schwarz and Laupper (1922), cellulose and lignine Kohl, vet- en eierkool, was- and hankool [Dutch names for various types of coal]. Pyrophorous iron (see also Noack, 1943) so called "Erdbrände" in coal seams may be caused by similar phenomena.

Foraminiferal ooze.

Guano. 10 metres near Iquique, Chile, formed in 1,100 years. Also, phosphate minerals.

Phosphate may accumulate from magma alone. Apatite 50-80%, nepheline 13-35% *etc.* from Fersman (1929).[37]

Graphite occurs as result of metamorphosis carbonaceous matter (Rhode Island).

Sulphur, the large and commercial deposits occur in sedimentary rocks and are generally the result of the reduction of sulphate minerals, notably gypsum.

[In pencil a calculation of the surface of the earth ending in "Surface earth = 5.12×10^{18} cm^2.]

Sphalerite, ZnS in sedimentary rocks.

Pyrite, FeS_2 decomposed to limonite and goethite. As nodules and excretions in many slates and sandstones (cubic).

Marcasite, (orthorhombic dipyramidal) concretions in marl, clay, limestone and coal. (*chalcopyrite*, $Cu_2Fe_2S_4$), *pyrolusite* (MnO_2). *hematite* (Fe_2O_3). *opal* ($SiO_2.xH_2O$).

27 According to K. Arens (1934) and Lausberg (1935), plants during the growing season lose through the leaves more potassium than on average is contained in the crop harvest. So this forms a sort of cycle of potassium between plants and soil. See also Arens and Lausberg (1946).

28 The following pages are written in ink and contain short notes mainly on organic sedimentary rocks. Many entries are from Correns (1939).

29 Kudo (1954), *Handbook of Protozoology*, p. 256:

> The chemical nature of the skeleton is used in distinguishing the major subdivisions of the group. In the *Actipylea* it seems to be made up of strontium sulphate, while in the three other groups of Radiolaria, *Peripylea*, *Monopylea* and *Tripylea*, it consists fundamentally of silicious substances.

Baas Becking evidently used a later edition of Kudo's *Handbook*.

30 Reference to Haquébard (1943). Caustobioliths are combustible organogenic rocks. They include caustobioliths of the coal – peat series, brown coal, hard coal or anthracite, and members of the bitumen – petroleum series.

31 Potonié described decomposition of organic matter and distinguished processes as: 1) *huminisation (coalification)* leading to humus, due to planktonic organisms, lower plants and protozoa and 2) *bituminisation (enrichment in hydrogen)*, leading to sapropel (decay slime), formed from the remains of higher plants.

32 Marie Charlotte Carmichael Stopes (1880-1958), English palaeobotanist, founder of modern coal petrography and campaigner for eugenics and women's rights. Her manual *Married Love* (Stopes, 1918) was controversial and influential. In 1935, Stopes published a paper refining the earlier nomenclature of coal. During the Second International Geological Congress on Carboniferous Geology in Heerlen (Netherlands), it was proposed that this nomenclature be accepted with certain modifications. Baas Becking probably referred to Stopes (1935).
See also Falcon-Lang (2008).

33 Baas Becking referred to Lieske (1929). Rudolf Lieske suggested that fusite (fusain) was formed as a result of "gas pockets" developing in the original peat. The plant material in the gas pockets was protected from impregnation with humic derivates of plant decay and from aerobic decay by a cover of colloid gels. The resultant anaerobic decay within the gas pocket formed fusain.

34 See Section 6.2.2. for reference to Schwarz and Laupper (1922). Also see Laupper (1920), for a report, and bibliography of the 'hay stack problem.'

35 Reference to Boekhout and Ott de Vries (1904-15). Boekhout and Ott de Vries did their investigations upon the heating of hay and tobacco in the Experimental Station at Hoorn. They concluded that microorganisms play no part in the phenomenon, which they attributed to purely oxidative chemical process in which the iron that occurs naturally in the plant acts as catalyser.

36 Maillard (1912). Maillard reactions, named after Louis-Camille Maillard (1878-1936), French physician and chemist, who discovered the reaction in 1912, is initiated by a condensation of amino groups on protein, peptides, and amino acids with carbonyl groups on reducing sugars. The reaction gives browned food a distinctive flavour. In food science, these reactions are named non-enzymatic browning reactions. In health and medical sciences, this process is known as protein glycation or glycoxidation.
See Lund and Ray (2017).

37 Soviet Russian geochemist and mineralogist Alexander Evgen'evich Fersman (1883-1945). Baas Becking referred to a 1929 published paper in which Fersman drew attention "to the possibility of using some side components of apatite-fluorine, strontium and rare earth, as well as nepheline and titanium-containing minerals." (Fersman ,1929). See Larichkin *et al.* (2020).

Limonite, $Fe_2O_3.H_2O$. *Halite*, NaCl, Sodium nitrate, $NaNO_3$ deposits 6-12 ft deserts of Atacama and Tampaca.[38] *Calcite* (hexagonal) $CaCO_3$, *Dolomite* $CaMg(CO_3)_2$, *Magnesite* $MgCO_3$. *Siderite*, $FeCO_3$ with sulphide ore deposits. *Aragonite* (rhombic) $CaCO_3$, *Anhydrite* $CaSO_4$ mixed with organic matter. *Celestite*, $SrSO_4$ in shales, limestones and dolomites. *Gypsum* $CaSO_4$.2aq, (monocline) in common salt deposits, in limestones and shales. *Epsomite*, $MgSO_4$.7aq non-hygroscopic. *Melanterite*, $FeSO_4.7H_2O$ efflorescence. *Magnetite*, Fe_3O_4 in black sands. *Apatite*, $Ca_5F(PO_4)_3$ = a. nodular, b. phosphate rock, c. guano, also $Ca_5Cl(PO_4)_3$. *Wavellite* $(AlOH)_3(PO_4)2.5H_2O$, (rarer). *Andalusite* Al_2SiO_5, often inclusions dark organic matter (*chiastolite*). *Dahllite*, $3Ca_3(PO_4)_2.2CaCO_3.H_2O$.

Kollophan, $Ca_3P_2)_8.H_2O$. *Vivianite*, $Fe_3P_2O_8.H_2O$.

Linné "*Omne calx ex vivo.*"

Allen (1934) finds influence of algae in Mammoth Hot Springs in precipitating travertine important. In cooler water the disposition of silica could be enhanced by functional activity of algae.[39] Adjacent springs myriads of living diatoms forming diatomaceous earth.

6.4 More Permanent Changes

"*L'influence des êtres infiniment petits est infiniment grande.*" [Louis Pasteur]

6.4.1 Introduction

The more permanent changes caused by organisms result from interference with the biological cycle. By suppression or inhibition of one or more chain processes inside a cycle, compounds may accumulate. They may be changed by later geochemical or geological forces, but the rhythm is interfered with. Only in special instances organic material may accumulate, usually the changes in the chemical environment only show in the mineral realm, although they are caused by biological agents. We shall mention:

Table 6.1 Scheme with items on more permanent changes in the environment that are dealt with in the following paragraphs.

	1. oxygen and carbon dioxide	
I. Changes in the atmosphere	2. pollution	
II. Changes in the hydrosphere	3. composition of natural water	
III. Changes in the lithosphere	a. organic material	4. caustobioliths
	b. inorganic deposits	5. lime
		6. dolomite
7. silica, 8. phosphate, 9. iron and sulphate, 10. salt, 11. glauconite, 12. concentration of rare elements, 13. quartz		

6.4.2 Changes in the atmosphere

6.4.2.a The composition of the atmosphere

An incandescent earth could hardly show any free oxygen in the atmosphere in contact with the lithosphere. The formation of oxides would consume the oxygen. V.H. Goldschmidt has called attention to this fact in 1923 and has elaborated the hypothesis that the ±21% oxygen in our atmosphere is entirely derived by the biological reduction of carbon dioxide, resulting in a gradual increase of the oxygen. Goldschmidt assumes a small initial amount of oxygen without which "life could not start."[40] Biologically, this assumption seems unnecessary. We know, and have treated these cases in this book, of many organisms which are utterly autotrophic and still able to persist without oxygen, if only free loosely bound hydrogen be available in the milieu. Goldschmidt gives, moreover, a geochemical calculation which should account, quantitatively, for the increase in oxygen in the atmosphere. His reasoning is as follows.

6.4.2.b Goldschmidt's geochemical calculation for increase in oxygen in atmosphere

The oxygen liberated in photosynthesis, may be used for the oxidation of organic material. As the respiratory quotient of this process, like that of photosynthesis, averages around the same numbers (1.00), this process contributes equally to the debt and credit side of the balance. Plants have to reduce the oxidised compounds NO_3-NH_3, SO_4-H_2S before animals can make use of them. This harks back, to the original earth, where everything was always honest! See also v. Tongeren. *Chem. Weekbl*. 32, 304 (1935).[41]

1. Part of the organic matter remains as humus or as caustobiolith. There should be a relation between the amount of oxygen liberated. [in the margin: This consumption has to be estimated lower, however, as the oxygen of sulphates becomes available, by its reduction, for the oxidation of other compounds, both inorganic and organic, such as H and organic acids. See for older literature, Clarke (1916), (Kelvin), Lénicque.][42]

2. Weathering of volcanic minerals, by which bivalent iron, manganese and pyritic sulphur are oxidised will consume a certain amount of oxygen.

3. Extracting consumption from production should give the amount of oxygen present in the atmosphere. This amounts to 0.232 kg/cm^2 earth surface. Now the amount sub 2 [see above = weathering of volcanic minerals] (oxidation of Fe^{2+}, Mn^{2+}, S^{2-}) may be estimated as 0.2-0.5 kg/cm^2. Therefore, the amount given as 1a should be 0.2-0.5 + 0.212 = 0.4-0.7 kg/cm^2, corresponding to 12/32 x 0.5 – 0.8 or 0.18 – 0.29 kg/cm^2 fossil carbon. This should be divided over 170 kg/cm^2 sedimentary rock yielding an average carbon percentage in the rock of 0.17%. This seems to be in good agreement with the analytical data.

It seems to the author, however, that not only the reduction of the carbon dioxide, but also other inorganic reductions may ultimately give rise to oxygen. Even if this is not atmospheric oxygen it should influence the amount of 2 [= weathering of volcanic minerals] as the sulphate

38 Before WW I the principal world source of nitrate was the Atacama Desert of Chile, where sodium nitrate occurred as a sort of caliche or evaporite in the dry subsoil of the desert. The coastal plain in Florida, east of Tampa produces workable deposits of apatite in limestone rocks.

39 Reference to Allen (1934).

40 Reference to Goldschmidt (1923).

41 Van Tongeren (1935), *De Ontwikkeling van de Geochemie in de Jongsten Tijd.*

42 Reference to H. Lénicque, 1903, cited by Clarke (1916, p. 57).

reduction is one of the most intense geobiological processes. Still, Goldschmidt's concept elucidates much that remains mysterious. Goldschmidt has, moreover, shown that, in order to satisfy the basic oxides originated by weathering ±6.5 kg/cm² CO_2 are necessary. In order to satisfy photosynthesis, we have to increase this value to 7.5 kg/cm² CO_2. This enormous amount may only be supplied by volcanic action.

In 1937, at a meeting of the Royal Netherlands Academy the author called attention to the great influence of Goldschmidt's concept on biology.[43] The earth is becoming increasingly aerobic and in as much as differentiation in organisms is caused by a large number of sugar metabolites, the formation and existence of which depends, to a large extend, in adequate redox potential (see also Ruhland, 1938).[44] It seems obvious that a region where differentiation is prepared (meristems of shoots and roots) should be kept at a certain maximum oxygen potential, above which the valuable ergones should be irretrievably oxidised. Meristems are, therefore protected. In buds by waxed or varnished scales. In *Aesculus* dwarfing seems to go parallel with the structure of the bud. Furthermore, plants related to those that, according to Goldschmidt should have lived, under considerably reduced oxygen pressure, in the Carboniferous era, like horse tails and *Lycopods*, show typically exposed, vegetation cones. In the Carboniferous epoch, about 500 million years ago, the atmospheric oxygen might have amounted to ±15% instead of 21% assuming a proportional increase of oxygen contents since the inception of a cooled earth about 2000 million years ago.

When dealing with the symbiosis problem of *Ardisia,* we have dealt with this matter (see Section 7.5.2).[45] Here we have a plant that apparently obtained 'too much' oxygen from our normal atmosphere. It seems not too far fetched to comment the enormous development of *Lycopods* and *Equisetes* (the poor remnants of which are now dragging out a precarious existence) with the favourable oxygen tension existing in those days. The problem seems capable of experimental approach. The influence of vegetation upon rainfall will be dealt with in Section 8 under deforestation.

Very important is the nitrogen fixation, apart from certain bluegreens (Galestin, 1933),[46] we have the aerobic *Azotobacter*, the symbiotic *Radiobacter* and the anaerobe *Closteridium pasteurianum*. All these forms need probably molybdenum. According to Virtanen (1930) they first form hydroxylamine, later NH_3.[47] The efficiency, as compared to Haber process, seems to be rather high (Baas Becking and Parks, 1925). See survey by Löhnis, (1943, *Vakblad voor Biologen*).[48]

6.4.2.c Pollution

Volcanic activity might cause high CO_2 content of the atmosphere. The influence of this high CO_2 tension in volcanic valleys on vegetation has not been investigated, as far as the author is aware. Von Faber investigated the plants that occur near solfataras on Javanese volcanoes - plants that are probably to a certain degree immune for SO_2 vapour.[49] We know from industrial damage caused by flume gases of smelters that SO_2 exerts a deleterious effect on many plants, especially on the photosynthetic apparatus. Apparently the SO_2 combines with chlorophyll. Large colonies of man (cities) cause a marked pollution of the atmosphere, especially around industrial areas: NH_3, toluene, benzene etc. are often present. Jacq has called attention to the fact that most species of *Lichens* seem to stream the town.[50] They appear as "père du organisms." The author has checked this idea in several waters in the vicinity of Rotterdam. Further anthropic influences shall be dealt with in Section 8 on Man.

6.4.3 Changes in the hydrosphere

[Baas Becking referred to Section 5.7.6.]

1. Photosynthesis and respiration. During photosynthesis alkalinity will increase until Ca, and later Mg, precipitate. Also, HCO_3^- decreases at the expense of CO_3^{2-} (K in Fig. 6.3 and arrow from A running N-E). Respiration causes the opposite changes in acidity, increase in Ca and Mg until dissolved.
2. Sulphate reduction and sulphide oxidation during sulphate reduction the oxygen disappears, the alkalinity increases (A in Fig. 6.3). The opposite takes place when sulphide is oxidised, water is created, oxygen tension increases, and acidity increases (see Section 9.6).

43 Reference not identified. Possibly he referred his lecture on *Symbiosis* in the *Verslagen KNAW* (1938, vol. 47, p. 67-70).

44 Wilhelm Otto Eugen Ruhland (1878-1960), German botanist and plant physiologist. The reference to Ruhland (1938) was not identified.

45 In the 1944 manuscript of *Geobiology*, the bacterial symbiosis in the nodules of leaves of *Ardisia crispa* was only stipulated. In the 1953 version of *Geobiology* (p. 623-625), Baas Becking referred in the Section *Foliar Bacterial Symbiosis* to the phenomenon, based on studies of Miehe (1911 and 1917) and P. De Jongh (1938). Baas Becking was the PhD advisor of Philip de Jongh.

46 Reference to Galestin (1933), Is elementary nitrogen absorbed by root nodules in the assimilation of nitrogen of air by the legumes? The research was done in the Delft Laboratory of Technical Biology, under supervision of Professor G. van Iterson jr.
During WWII Casper J.A. ter Galestin (1905-1944) was a member of the The Hague Underground Resistance. In December 1943 he was arrested in Belgium and was shot in Vught in September 1944.

47 Reference to Virtanen and Vantiansen (1930). The classic 'hydroxylamine theory' or 'oxime theory' was proposed in 1930 by Virtanen, who claimed that hydroxylamine functioned as an intermediate in nitrogen fixation by the symbiontic system consisting of a leguminous plant and *Rhizobium*. Since then, there has been a series of controversies on the biological occurrence of hydroxylamine in various nitrogen fixing systems of aerobes (*e.g.*, *Azotobacter*) or anaerobes (*e.g.*, *Closteridium*). No reproducible and biochemically appreciable appearance of hydroxylamine in the nitrogen fixation process has been reported. *Circa* 2000 the use of the stable isotope ^{15}N as tracer resolved the argument. When ^{15}N-enriched N_2 was supplied to a culture of *Azotobacter vinelandii* fixing N_2 vigorously, and among the amino acids recovered from the hydrolysate of the cells the highest ^{15}N enrichment was in glutaminic acid rather than in aspartic acid, which would have been supportive of Virtanen's hypothesis. In similar experiments with *Closteridium*, *Chromatium*, *Chlorobium* and *Rhodospirillum* as well as the bluegreen alga *Nostoc muscorum*, the highest concentration of ^{15}N among the isolated amino acids was in glutamine.
See Burris (2017).

48 Reference to Löhnis (1941). Maria Petronella Löhnis (1888-1964), Dutch phytopathologist, microbiologist, botanist, noted for studying potato diseases. See also Wieringa (1964).

49 Friedrich-Carl von Faber (1880-1954) German botanist, plant physiologist in Java (1909-1930), Professor of Botany, University Vienna (1930) and in 1935 in Munich. During WWII Von Faber was dean of the Faculty of Natural Sciences in Munich and a supporter of "Aryan physics." He was not willing to oppose against the NAZI intended dismissal of Karl von Frisch as Professor of Zoology from the Munich University. See Deichmann (1996, p. 47-49, 70, 79).
Baas Becking referred to Von Faber (1925 and 1927). According to Thomas and Jasieński (1996):

> Von Faber's attention was initially drawn to CO_2 vents by the presence of extremely green leaves of plants in the immediate vicinity of the vents. He later documented that these plants did in fact show exceptionally high chlorophyll content. Von Faber also speculated that high CO_2 levels could compensate for very low light levels, facilitating the evolution of extreme shade plants in such environments.

50 The reference is to Nikolaus Joseph von Jacquin (1727-1817), born in Leiden where he studied medicine afterwards Paris and Vienna. One of his interests was mycology. Standard author abbreviation is Jacq. Von Jacquin is known for the large collection of plant, animal and mineral samples collected for the Schönbrunn Palace.

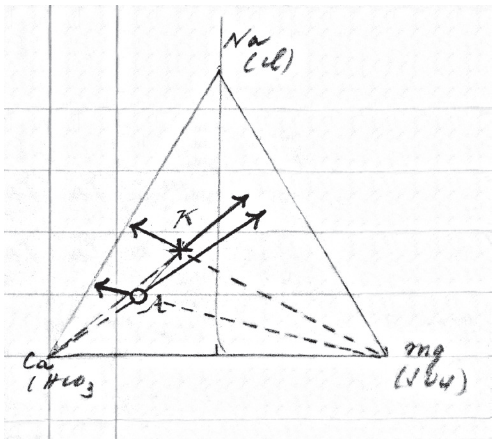


Figure 6.3 Equilateral triangular plot with compounds Na(Cl) – $Ca(HCO_3)$ – $Mg(SO_4)$ showing changes in chemical composition of natural waters by photosynthesis and respiration and by sulphate reduction and sulphide oxidation.

3. The origin of the acidity in bog water will be treated in Section 9, see also Section 3.7. The oxidation of sulphur by the formation of sulphuric acid, and acid ferrisulphate causes oxidation sometimes higher than 1N H_2SO_4 (pH = 0). These oxidations are obtained by means of a 'living catalyst' *Thiobacillus thiooxidans* (Waksman and Joffe, 1922).

[in the margin:]

[4]. Denitrification and oxidations.

[5.] Cellular fermentation sequences $CaCO_3$ *etc.*

See also Figure 5.14.

6.4.4 Changes in the lithosphere

6.4.4.a Caustobiolithes

F.E. Hecht: "*Der Verbleib der Organischen Substanz bei Meerischer Einbettung.*" *Senckenbergiana* 15 (1933, p. 165-249). Chemical decomposition of animals. Krejci-Graf, K., *Oelgeologische Thesen*, Berlin (1931).[51]

6.4.4.b Oil

Petroleum is of biological origin (optimal activity, substance like chlorophyll and haemoglobin). Petroleum originated from an original bitumen, probably anaerobically (under H_2S?), probably marine, diatoms, benthos, fishes, coproliths? (Hecht).[52] Hyles obtained oil by distillation of algae. Thayer tied fatty acids R-COOH to decarboxylation, he obtained methane in the whole series up to inorganic acid.[53] Frank found no oil in recent sediments.[54] Adipose is only slightly changed animal fat. It is probable that oil originated in alkaline milieu. In 10 years, fat of a shark not materially changed olive glycerol. From diatom oil Hashimoto a whole bouquet of sterols. But origin of oil remained as obscure as ever.[55]

6.4.4.c Humus and Coal

Glucose is the mother substance of all caustobiolith formations. There is a road from glucose to fatty substances which according to Haehn and Kintoff (1923 and 1924),[56] originates from lower fatty acids by unsaturation. It is possible that from the fatty materials the heterogenous mass known as "oil" arises (*line 1* in Fig. 6.4). In this phase of carbonisation the carbon is still in the diamond grating (aliphatic). In anthracite and graphite we already find the typical graphite grating (laminar). In carbonisation the diamond grating is left for the graphite C, aromatic compounds have to be converted [?] before we reach the carbon. As *line 2* in Figure 6.4 is more than a straight dehydration, hydrogenation also plays a role. Finally, caramelisation, as shown by Schweizer is nothing but the reversal of water from the sugar molecule, but rather none than in the formation of the cellular chain.[57] This should follow *line 3*. The series lignine → brown coal → cannel coal → anthracite is non-biological and takes place in an anaerobic, alkaline milieu, where most of the organic substances disappear by bacterial activities (eutrophic plankton). Fatty substances remain but there is not a shred of experimental evidence as to how oil originates from them. Caramelisation may take place in the presence of oxygen. It may be, in certain cases, a vital process (formation of phytomelanins). For nomenclature see Potonié (1910), Haquébard (1943).

While carbonisation to caramel or anthracite takes centuries to perform, caramelisation may proceed quite rapidly. De Vries has shown that the black 'humic' substance in ebony and in composite fruit (sunflower),[58] the so called phytomelanins are probably identical with caramelisation products of sugar. The carbon is, as micro X-ray by Mr. D. Krejer [=K. Kreji-Graf (1930)] showed, amorphous.

51 Baas Becking possibly referred to Krejci-Graf (1930).

52 Reference to the above mentioned publication of Franz E. Hecht.

53 Thayer (1931). Thayer showed the production of hydrocarbons by bacteria, however there is no evidence that higher molecular weight hydrocarbons, other than methane, can be produced by bacterial activity. Lewis A Thayer made the literature review for Baas Becking *et al.* (1927).

54 Possibly reference to Frank (1932).

55 Reference to Baas Becking *et al.* (1927).

56 Baas Becking referred to "Hahn and Kientopf" see also Section 3.9.1. The correct reference is to Haehn and Kintoff, who in several papers (1923-1926) published their studies of the chemical mechanism by which fat was formed from carbohydrate. Dr. W. Kintoff was during WWII involved with chemical warfare. In 1935, he was author of *Chemistry Experiments with War Material for Schools*, which according to the author, "older pupils in the People's Schools can get much information from it which will be of service to them for the Fatherland, when it calls them". Source: Norman Angell (1938), *Education in Nazi Germany.* Kulturkampf Association 19 Southampton Buildings, Chancery Lane London, page 45. The Kulturkampf Association was an organisation of anti-fascist Christians and Jews, who informed the English public about the spiritual and religious propaganda that was going on in Nazi Germany.

57 Reference to Matthias Eduard Schweizer (1818-1860), Swiss chemist, known for his 1857 invention of Schweizer's reagent, in which cellulose can be dissolved for the production of artificial silk.

58 Refers to the research of Mechteld Anna de Vries published in her PhD thesis (1948). In the manuscript of *Geobiology* (1953a, p. 245) Baas Becking wrote:

> In certain instances, the cell wall material may undergo, at room temperature, a veritable carbonisation with the formation of black compounds, phytomelanes. M. de Vries (1947) [= 1948], at the Leyden Laboratory, has shown that in the seed coats of such *Compositae* as the sunflower and the African daisy, these black compounds (containing, judging from the X-ray picture, Carbon in the amorphous state) may originate in a few days. Elementary analysis has shown these compounds to have a composition $C_x(H_2O)_y$, veritable "carbo-hydrates" in the original sense of the word!

In the 1953 *Geobiology* manuscript, p. 576, he referred again to her research in the Leiden Botanical Laboratory:

> The processes of coal and hydrocarbon formation also take place in the living cell. A great variety of hydrocarbons is formed by both plant and animal cells and the phytomelans, highly carbonised compounds in the seed coat of composites (sunflower, African Daisy) are formed in a few days by caramelisation of carbohydrates in or near the cell wall (de Vries, 1948).

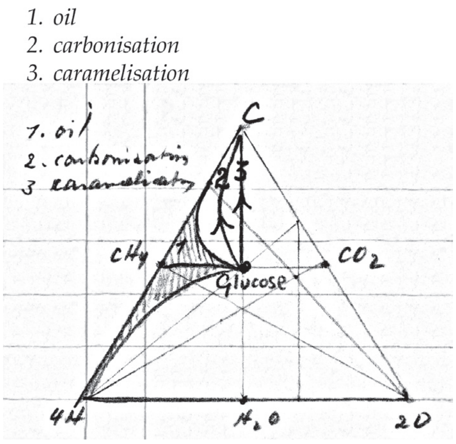


Figure 6.4 Equilateral triangular plot with compounds C – 4H – 2O, showing caustobolith formation from glucose: line 1 oil; line 2 carbonisation; line 3 caramelisation.

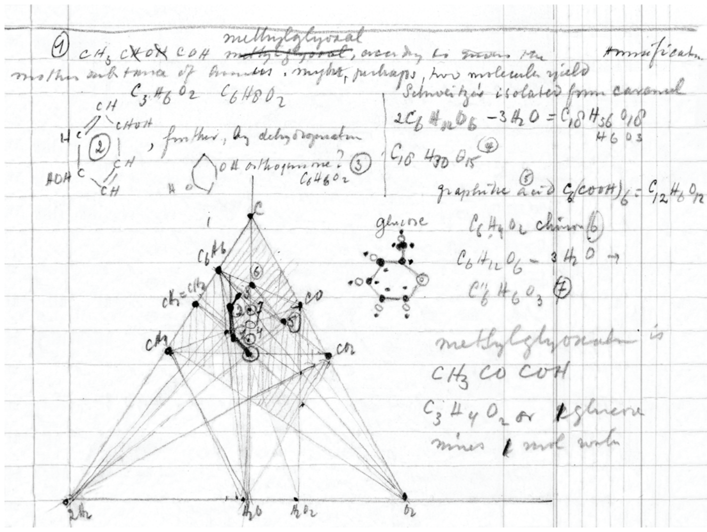
6.4.4.d *Bitumens and ichthyol*[59]

Here the possibility for participation of animal remains is much greater than in petroleum oil, as many fish remains are found in ichthyol and as, near Rancho La Bréa, California,[60] the excavated organisms are equally recognisable.

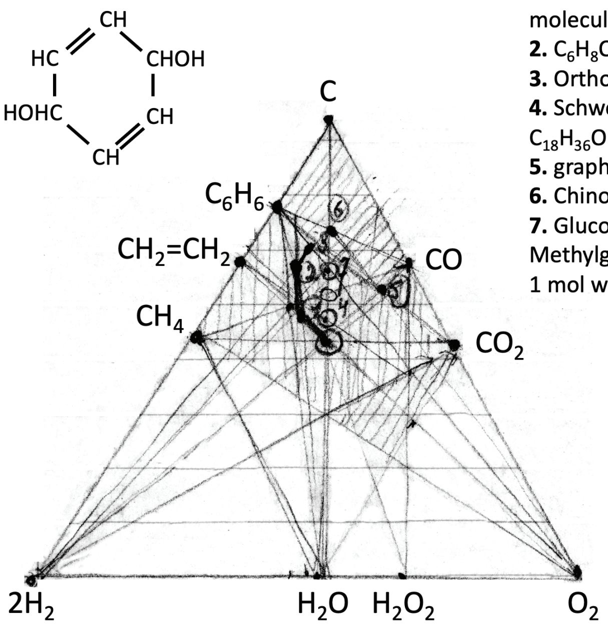
6.4.4.e *Other organic compounds*

Chitin is found in trilobites, in all 'closed universe' (Section 7.9.2). *Bacillus chitinovorus* of Benecke (1905) seems to have little appetite![61] *Lignine* is found in coal, in all fossil and subfossil pollen grains, thus enabling us to reconstruct the flora of glacial epochs. *Chlorophyll* was found by Treibs in petroleum.[62]

[Baas Becking inserted in the paragraph Fig. 6.5, Table 6.2 and Fig. 6.6. These figures and Plate 3.1 in Section 3.5.15, give in more detail the changes in composition of the organic compounds during the processes of humification, caramelisation and carbonisation. In the figures Baas Becking referred to Curt Enders.[63]]



1. CH_3COH methylglyoxal according to Enders, the mother substance of humus might, perhaps, two molecules yield $C_3H_6O_2$ and $C_6H_8O_2$
2. $C_6H_8O_2$ (in formula), further, by dehydrogenation
3. Orthoquinone $C_6H_6O_2$
4. Schweizer isolated from $2C_6H_{12}O_6 - 3\ H_2O =$ $C_{18}H_{36}O_{18}\ - H_6O_3 =\ C_{18}H_{30}O_{15}$.
5. graphite acid $C_6(COOH)_6 = C_{12}H_6O_{12}$
6. Chinon $C_6H_4O_2$
7. Glucose $C_6H_{12}O_6 - 3\ H_2O \rightarrow C_6H_6O_3$
Methylglyoxal is CH_3 CO COH, $C_3H_4O_2$ or glucose minus 1 mol water.



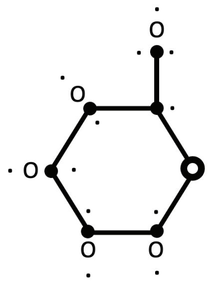


Figure 6.5 Equilateral triangular plot with compounds C – 4H – 2O, showing methylglyoxal formation from glucose.

59 Ammonium bituminosulfonate or ammonium bituminosulphonate (synonyms of ichthammol and Ichthyol) is a product of natural origin obtained in the first step by dry distillation of sulphur-rich oil shale (bituminous schists). By sulfonation of the resulting oil (or purified fractions thereof), and subsequent neutralisation with ammonia, Ichthammol results as a viscous, water soluble substance with a characteristic bitumen-like odour.

60 La Brea Tar Pits group of tar pits around which Hancock Park was formed in urban Los Angeles.

61 Reference to Benecke (1905). Benecke isolated the bacterium from water in the Kiel harbour and was the first to describe a bacterium which used chitin as a food. The current name of the species is *Beneckea chitinovora*.

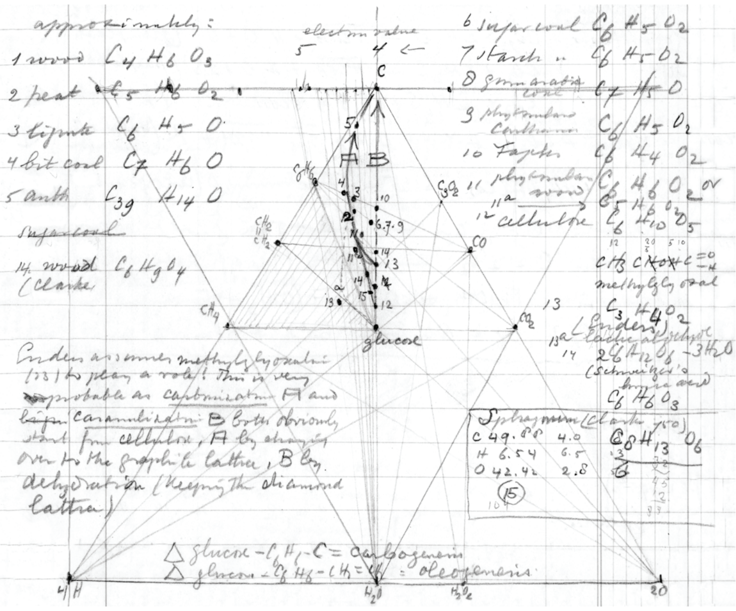
62 Reference to Alfred E. Treibs (1899-1983), German chemist founder of organic geochemistry. Treibs discovered metalloporphyrins in petroleum. These porphyrines resemble chlorophylls. This discovery helped to confirm the biological origin of petroleum. See Treibs (1936).

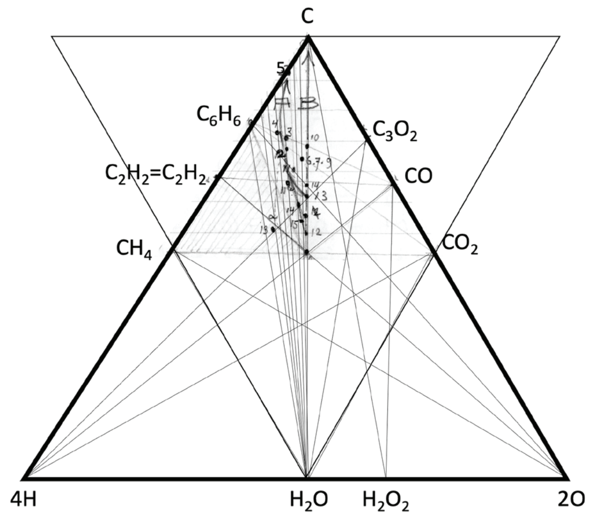
63 Baas Becking possibly referred to Enders (1943), *Wie entsteht der Humus in der Natur?*

Table 6.2 Average composition of fuels from Clarke (1916, p. 763).

	C	H	N	O	
Wood	49.65	6.23	0.92	43.20	The last three values (artificial coal) from Frémy (1879, *Comptes Rendus* 88, p. 1048).[64]
Peat	55.44	6.28	1.72	35.56	
Lignite	72.95	5.24	1.31	20.50	
Bituminous Coal	84.24	5.55	1.52	8.69	The values for phytomelanin are from a letter of de Vries (July 1944).[65]
Anthracite	93.56	2.81	0.97	2.72	Frémy heated these substances in sealed glass tubes at 300 °C
(Artificial) Sugar Oil	66.84	4.78		28.43	
Starch	68.48	4.68		26.84	*c.f.* Dafert and Miklauz (1910) average of 6, prune, neefem [?], mahogany, iron-heart, Tlama, Coromandel
Gum Arabic	78.78	5.00		16.22	
Phytomelanin *Tagetes*	71.51	3.59		24.90	Lignin, Croon and Bevan
Phytomelanin *Carthamus*	67.10	4.67		28.23	$C_{12}H_{18}O_9$?
Phytomelanin from wood	57.00	5.60		36.00	Wood ± $C_6H_9O^4$

Wood	$C_{4.1}H_{6.25}O_{2.7}$	Sugar Coal	$C_{5.6}H_{4.8}O_{1.8}$
Peat	$C_{4.6}H_{6.3}O_{2.2}$	Starch Coal	$C_{5.}H_{4.7}O_{0.7}$
Lignite	$C_{6.0}H_{5.2}O_{1.3}$	Gum Arabic	$C_{6.6}H_{5.0}O_{1.0}$
Bit[umen] Coal	$C_{7.0}H_{5.6}O_{0.5}$	Phytomelanin Carth[amus]	$C_{5.6}H_{4.7}O_{1.8}$
Anthracite	$C_{7.8}H_{2.8}O_{0.2}$	Phytomelanin Tag[etus]	$C_{6.0}H_{3.6}O_{1.6}$
		Phytomelanin wood	$C_{4.7}H_{5.6}O_{2.2}$





1. Wood $C_4H_6O_3$;
2. Peat $C_5H_6O_2$;
3. Lignite C_6H_5O;
4. Bit coal C_7H_6O;
5. Anthracite $C_{39}H_{14}O$;
6. Super coal C_6H_5O2;
7. Starch coal C_6H_5O2;
8. Gum arabia coal C_7H_5O;
9. Phytomelanin Carthamus $C_6H_5O_2$;
10. Tagetus $C_6H_4O_2$;
11. Phytomelan wood $C_6H_6O_3$ or **11a.** $C_5H_6O_2$;
12. Cellulose $C_6H_{10}O_5$;
13. Methylglyoxal $C_3H_4O_2$ (Enders); **13a** Lactic aldehyde $2C_6H_{12}O6 – 3\ H_2O$ (Schweizer's humic acid) $C_6H_6O_3$
14. Wood $C_6H_9O_4$ (Clarke);
15. Sphagnum (Clarke, p. 150) $C_8H_{13}O_6$: C 49.88 4.0, H 6.54 6.5, O 42.42 2.8.

Enders assumes methylglyoxaline (13) to play a role! This is very probable as carbonisation (A) and caramelisation (B) both obviously start from cellulose. A by changing over the graphite lattice, B by dehydration (keeping the diamond lattice).
Δ glucose – C_6H_6 – C = carbogenesis
Δ glucose – C_6H_6 – CH_2 = oleogenesis.

Figure 6.6 Equilateral triangular plot with compounds C – 4H – 2O, showing organic components of carbonisation (A) and caramelisation (B). The line through C (carbon) on the top represents the 8 electronic valences of carbon.

64 Reference to Edmond Frémy (1814-1894), French chemist in 1850 successor of Gay-Lussac on the chair of chemistry of the Natural History Museum in Paris. Frémy subjected peat, lignite, wood and cellulose to enormous pressures and found indications that the effects of pressure alone do not convert such substances into humic coals.

65 See for research M.A. de Vries. Section 6.4.3.a. Evidently Miss Mechteld Anne de Vries sent results of her PhD research to Baas Becking in the Utrecht prison in July 1944.

[Baas Becking made the following additional remarks in Fig. 6.6.]

Enders (1943) assumes methylglyoxaline (13) to play a role! This is very probable as carbonisation (A) and caramelisation (B) both obviously start from cellulose. A by changing over the graphite lattice, B by dehydration (keeping the diamond lattice).

Δ glucose – C_6H_6 – C = carbogenesis

Δ glucose – C_6H_6 – CH_2 = oleogenesis.

6.4.5 Inorganic deposits

6.4.5.a Lime and Dolomite

In Section 3.6, it has been stated that due to the low solubility product (10^{-8}) of $CaCO_3$ this substance should precipitate from seawater, were it not for its tendency to form oversaturation and colloidal solutions. The influence that makes $CaCO_3$ precipitate are;

1. Changes in the physical environment such as pressure and temperature, which change the solubility of the $CaCO_3$.
2. Changes in the chemical environment resulting in an increase of pH or [CO_3^{2-}] or both. Among the latter we will name:

   a) Photosynthesis,

   b) Internal deposition,

   c) Secretion of alkali,

   d) Photosynthesis will alter the carbon dioxide equilibrium in a water. It will decrease the [H_2CO_3] and [HCO_3^-] and cause therefore [CO_3^{2-}] to increase, with concomitant increase in pH. Baas Becking and Irving (1924) found, in *Corallines*, a preliminary increase in pH of seawater in the light (Fig. 6.7).[66]

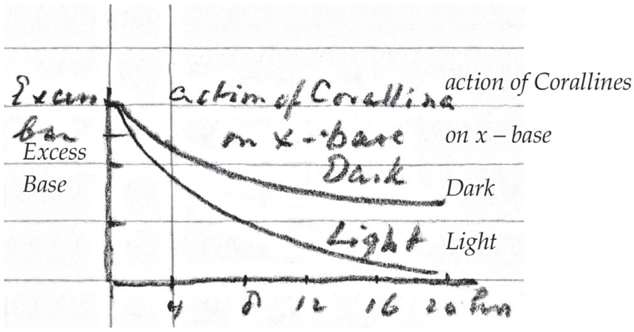


Figure 6.7 Rough sketch of decrease of $CaCO_3$ (base excess) from seawater by Corallines in light and dark (adapted from Irving and Baas Becking, 1924). $CaCO_3$ excess drops 13.10^{-4} normality in light and $8.5.10^{-5}$ normality in dark in 24 hours.

The entire excess base had been exhausted by internal deposition of $CaCO_3$ (in the light), which also takes place in the dark. 8 g algae deprived 10 litres of seawater of its entire excess base in 18 hours.[67] Shells, corals and the like also are able to deposit lime in the dark, probably by pH increase in the internal milieu. Hubert (1935) found that a water moss *Fontinalis* was able in the light, to increase the pH up to 10.[68] Close to the precipitation point of organic salts! The natural, original formation of dolomite needs not be diagenetic as assumed by most authors (Correns, 1939, pp. 200-202). Arisz claims that aquatics are able to secrete $Ca(OH)_2$ from one side of the leaf (*Elodea, Valisneria*).[69] The old controversy about the action of the *Bacillus calcis* of Drew (1914), which should be active in the deposition of lime near the Bahama's,[70] has lost much of its sharpness since Bavendamm (1931) showed that in Tortugas lime deposition will take place everywhere bacteria excrete alkali (probably NH_3) into the outer milieu.[71] The Pasteur *Bacillus urea*, which deoxidises urea according to

$$\begin{array}{lll} \quad NH_2 + HOH & \quad OH & \\ / & / & \\ C = O \quad \rightarrow & C = O & + 2\,NH_3 \\ \backslash & \backslash & \\ \quad NH_2 + HOH & \quad OH & \end{array}$$

should be considered here; the more so as their milieu limits seem very wide.[72] They are eurybionts [animal or plant organisms capable of surviving under substantial changes of

66 Reference to Irving and Baas Becking (1924). Baas Becking (1934, 2016) discussed this case in Chapter IX. Figure IX.5 (in 2016 version) and in Irving and Baas Becking (1924) show the base excess absorbed by Corallines in dark and light. In the figure in the 1944 manuscript of Geobiology Baas Becking plotted the decrease of the base excess in seawater.

67 In *Geobiologie* (Baas Becking, 1934, p. 38-45), Baas Becking explained the equilibrium of carbon dioxide in water with charged bicarbonate and carbon ions and the mechanism of carbon dioxide exchange. He further explains the term of "base excess to mean the number of equivalent metal ions in a certain amount of water that is in equilibrium with hydrogen, hydroxyl, bicarbonate and carbonate.

68 B. Hubert was a PhD student of Baas Becking in Leiden. In 1935 he wrote his thesis, *The Physical State of Chlorophyll in the Living Plastid*, under Baas Becking's supervision.

69 Baas Becking referred to the research W.H. Arisz of the Groningen Botanical Institute. Arisz (1945) discussed,

> […] the ability of plant cells to take up salts from their environment. From vegetation experiments, it has appeared that plants can absorb inorganic salts even from very dilute solutions. […] Whereas it was originally thought that the salts are carried along by water that the plant takes up as a result of transpiration, it has become clear in later years that the uptake of salt is a complicated process, which though it may be more or less affected by water absorption, for the rest takes place independently of it. So, it comes to pass that also submerged water plants, which naturally show no transpiration, yet take up nutrient substances as salts and aminoacids from the environment. This is partly done by their roots, partly by their leaves, as for instance *Elodea* and *Vallisneria*.

70 Reference to Drew (1914). The bacillus held responsible for the precipitation of calcium carbonate was named by Drew *Bacterium calcis*, and subsequently was shown to belong to the genus *Pseudomonas*. Cultures of this bacillus made by Drew indicated that it is capable of changing calcium nitrate to calcium carbonate, and he supposed a similar action to take place in seawater. Drew suggested,

> That *B. calcis*, or other bacteria having a similar action, may have been an important factor in the formation of the various chalk stata in addition to the part played by the shells of *Foraminafera* and other organisms in the formation of rocks.

Later studies attacked the conclusions of Drew and considered that there is no support for his explanation of the mechanism of $CaCO_2$ precipitation in natural waters. See Twenhofel (1926, p 237-238).

71 Bavendamm (1931, 1932) concluded that there are no specific calcium bacteria, although he believed that microbiological calcium precipitation in tropical seas may be an important process, particularly in mangrove swamps where the organic content and bacterial population are high. In the 1934 edition of *Geobiologie* Baas Becking referred to the research of Drew and Bavendamm (Chapter IX, p. 98, English edition).

72 Pasteur ascribed in 1859 the cause of ammoniacal urinary disorders to bacteria. The conversion of urea into ammonia is a function possessed by a number of bacteria. The earlier observations of Pasteur, Miquel and others showed that various large spore forming "urobacilli" could be isolated from air, soil, and sewage, and, later, many other bacteria were found able to form small amounts of ammonia from urea.

environmental conditions] as far as salt tolerance is concerned (Hof, 1933).[73] For further considerations in relation to lime deposition see Section 6.6.5. The oversaturation of seawater in $CaCO_3$ and its increase with increasing temperature is described in Section 3.6.[74]

6.4.5.b Silica

Senckenbergiana, bd 11, p. 160 (Schwarz, 1929).[75]

Lydites in deep sea radiolarite.[76] Flint is made out of sponge needles. Van Niel, Yellowstone, found travertine terraces probably from oversaturated SiO_2 solution. Silica precipitated by bluegreen algae through dehydration locally by photosynthesis, where water is absorbed. Rivers are under estimated in silica (See also 6.6, *Sediments*). Solubility function of pH. Certain plants accumulate silica, grasses and palms, often in stigmata, further *Equisetes*. In Bamboo often very porous connections of pumice-like consistency, entirely formed by opal (= colloidal amorphorous SiO_2), 'tabashir' (absorbs gases readily).[77]

6.4.5.c Phosphate

Except for P in magnetic rocks and such minerals, [apatite, wavellite, andalusite, chiastolite, dahllite, collophan, vivianite], all phosphate is of organic origin. Bones contain up to - -, guano - - -.[78] Phosphate ion may not be reduced by plant cells, although there are claims that the 'will-o-the-wisp',[79] the light over a marsh may be due to spontaneous combustion of PH_3, originated by reduction of a diphosphate. Arens and Lausberg found excretion, of $K_2H_2PO_4$ by leaves.[80] Van den Honert found $H_2PO_4^-$ ion only P compound absorbed by super ion.

6.4.5.d Iron, sulphur and sulphate

As iron is usually only very slightly soluble in a natural water it must be surmised that most of the biochemical reactions in which iron plays a role, it should be in colloidal solution. The sulphate reduction forms sulphide in which, above a pH = 5 forms black FeS with ferrous salts. This FeS is probably the greatest oxygen consumer in nature as its oxidation by $Fe_2O_3 + H_2SO_4$ requires 7 atoms of O *per* molecule of pyrite oxidised. Part of this process (FeS → S) is chemical, part (S → SO_4^{2-}) is biological (see Verhoop (1940), Section 7.9.4 and Section 6.5). Another chemical reaction is FeS + S with the formation of pyrite FeS_2. If marcasite is formed in this way is unknown. Vaas claims to have demonstrated an accelerating action of iron bacteria (*Gallionella*) upon the reaction $Fe^{2+} \rightarrow Fe^{3+}$ (see also Section 7.6.4). $Fe_2(SO_4)_3$, and $FeSO_4$ also occur in nature where *Thiobacteria* and FeS react under the influence of oxygen.

6.4.5.e Salt

Certain Halophytes (*Salicicornia*) resist to severe salt NaCl.[81] According to Keys and Wilmer (1932), the eel has the power in a special gland to excrete NaCl.

6.4.5.f Glauconite

May be Echinoderm coprolith, according to Galliher (1935 and 1939) it is formed from biotite.[82]

6.4.5.g Guano

Is bird excrement saturation young chalk.

6.4.5.h Concentration of rare minerals

[in margin: Correns (1939, pp. 218-235) claims that all gypsum is of marine origin. If S deposits are – biological – why should not $CaSO_4.2H_2O$ originate from them?].

73 Reference to Hof and Frémy (1933). Baas Becking (1934) referred to T. Hof in Chapter X, p. 120-121, English edition. She defended her PhD thesis (Hof, 1935a), *Bacteria Living in Strong Brine*, in 1935 in Leiden, Baas Becking was her PhD advisor.

74 Baas Becking discussed the precipitation of calcium carbonate in Chapter IX of *Geobiologie* (1934) (p. 97-98 in the English edition, 2016). In Chapter VI.6.5. Baas Becking discussed the lime deposition in natural waters and particularly seawaters.

75 For A. Schwarz in *Senckenbergiana* see also Section 6.6.3.

76 Radiolarite is a siliceous comparatively fine grained chert-like and homogeneous sedimentary rock (called lydits) that is composed predominantly of the microscopic remains of radiolarians. Radiolarites are biogenic, marine, finely layered rocks.

77 'Tabashir', a hard, whitish, translucent substance extracted from the nodal joints of bamboo, chiefly composed of silica. In the 1953 version of *Geobiology* (Baas Becking, 1953a, p. 526-527) Baas Becking wrote:

> In the hollow stem of the bamboo sometimes large accumulations of a very porous SiO_2 occur. These masses, called 'tabashir' may absorb large quantities of gas. They are used in native medicine. The metabolism of the silicon is still utterly unknown. The element is closely allied to carbon and like carbon, it may form chains, and a great number of Si-O-H compounds and C-Si-O-H compounds are described.

78 Baas Becking wrote in Chapter VI.4 in ink on phosphor containing minerals.

> *Apatite*, $Ca_5F(PO_4)_3$ = [a.] nodular, b. phosphate rock, c. guano, also $Ca_5Cl(PO_4)_3$. *Wavellite* $(AlOH)_3(PO_4)2.5H_2O$, (rarer).
> *Andalusite* Al_2SiO_5, often inclusions dark organic matter (*Chiastolite*). *Dahllite*, $3Ca_3(PO_4)_2.2CaCO_3.H_2O$.
> *Kollophan*, $Ca_3P_2)_8.H_2O$. *Vivianite*, $Fe_3P_2O_8.H_2O$.

Recent research learns that in humans, the majority of phosphate (~85%) is actually present in hard tissues that form through biomineralisation. Red Guano, a biogenic sediment is a pure phosphate fertiliser with 20-30% phosphoric acid content (P_2O_5). White guano refers to the guano that is produced daily by animal excrements – especially sea birds. It consists of 10-12% phosphoric acid.

79 'Will-o'-the-wisp', or 'ignis fatuus', in folklore is an atmospheric ghost light seen by travellers at night, especially over bogs, swamps or marshes. Modern science often explains them as natural phenomena such as bioluminescence or chemiluminescence, caused by the oxidation of phosphine (PH_3), diphosphane (P_2H_4) and methane (CH_4) produced by organic decay.

80 According to Arens (1934) and Lausberg (1935), plants during the growing season lose through the leaves more potassium than on average is contained in the crop harvest. This process does not occur passively during transpiration, and is due to active mechanisms. So, this forms a sort of cycle of potassium between plants and soil.
In the 1953 manuscript of *Geobiology* (p. 665) Baas Becking wrote: "It is known by the work of Arens (1934) and Lausberg (1935) that leaves may excrete large amounts of mineral matter."

81 For *Salicornia* see Patel (2016).
March 24, 1936 Baas Becking together with his assistent Dr. J. Reuter visited Lake Fowler in South Australia. In the 1953 version of *Geobiology* Baas Becking wrote:

> This lake measures more than four miles on its W-E diameter. The gypsum cliffs on the S-E shore are more than 70 ft high (see figure). […] It affords a most unusual spectacle, (never seen by me anywhere in the world). Viewed from the north the salt crust tapers off to a tough greyish mat, covering most of the southern part of the lake to the shore where the snowy-white cliffs, covered with peacock green and crimson "samphire" (*Salicornia* and *Halicnemum* sp.) and bluish-black *Melaleuca* trees from a long wall under the blue sky. On top of the cliffs a complete collection of salt plants occurred, including *Mesembryanthemum.* A beautiful mirage made us see a vast sheet of non-existent water towards the north.
> The dusty tessellated crust which covered the southern lake be for several hundred yards covered a thin layer of gypsum and salt crystals, overlying a thin stratum of black mud, where the sulphate was reduced down to a depth of 5 centimetres. Beautiful gypsum crystals up to one centimetre long occurred in the grey sand underlying this black mud. With an air temperature of 21.6°C (9.15 a.m.) we found at 12 cm depth 20°C. At the N.W. end of the lake, we found an expanse of pinkish salt, about 5 mm thick below which there occurred a layer rich in iron oxide, 3mm thick overlying several thin layers of black mud, alternating with gypsum. At places, the "crust" was developed as on the southern shore. With an air temperature of 26.4°C we measured, immediately under the crust.

82 According to Galliher (1939):

> In examining a number of glauconite sediments, a surprising amount of evidence is found tying glauconite to a biotite or iron mica derivation. Principal evidence for relationship lies in series of transition grains demonstrating gradual change from mica to glauconite.

6.5 Criteria for Geobiological and Geochemical Influences

There is often considerable doubt as to the cause of a geochemical process. Let us consider, as an example, the organisms playing a role in the sulphur cycle. As described by Bunker (1936), Ellis, Bavendamm (1931 and 1932), and others. Here we have a number of chemical processes for which either a microbiological or a chemical cause has been ascribed. A detailed study of a number of these processes was performed by Verhoop (now G.J.A. Iterson Jr.) in her Leyden doctor's thesis.[83] Natural black mud (finely divided FeS in clay) originated by biological sulphate reduction, oxidises at the air, according to

$$4FeS + 3O_2 = 2Fe_2O_3 + 4S.$$

Aerobically, the sulphate originated is oxidised further to sulphate into sulphonic acid. Verhoop measured the oxidation of the pyrite (hydrotroilite) colourimetrically and found a steady acceleration of the process up to 100 °C, the Q_{10} being in the neighbourhood of 2.0. If the process had been a biological one, temperature over 40-50 °C would show a retardation of the process. It may be concluded therefore, that the oxidation of black mud at the air is a *chemical, non-biological process*.

It has been stated repeatedly that the oxidation of sulphur at the air may take place without the influence of organisms, particularly when catalysed by ultraviolet light. However, the process is exceedingly slow under sterile conditions, as Miss Verhoop has been able to show. If a bit of soil is added to the culture media the process is enormously speeded up and the *Thiobacillus*, therefore, actually catalyses the exothermic reaction:

$$S + 2O_2 \rightarrow SO_4^{2-}.$$

We shall not hesitate to name this reaction an example of a *geobiological process*. From the thesis cited, it also appeared that, under anaerobic and sterile conditions pyrite (FeS_2) originated from troilite FeS and S, as both mineralogical and X-ray control showed. The process $FeS + S \rightarrow FeS_2$ is, therefore, *non-biological.* Of a great many processes, however, the cause remains obscure, of others the cause is contested. Modern mineralogy, for example (Escher, 1939) claims biological origin for (sedimentary) sulphur deposits, while Correns (1939) claims all gypsum deposits (which could easily originate from sulphur by oxidation in the presence of Ca and Mg) are of marine origin and are derived from evaporated seawater.

In the section on calcareous sediments, we shall meet with a similar controversy. Natural waters may become easily supersaturated with calcium carbonate. The work of the Laboratory of the Senckenbergianum, however, has shown, how careful one has to be to exclude biological influence in calcite deposition from supersaturated solutions! A peculiar problem is given by the so called self combustion of hay, a problem closely related to that of temperature increase during fermentation of tobacco leaf and high temperature measured in the spathe of certain Araceous flowers (van Herk, 1937) or *Nymphaeaceae*. Relegated, in the older literature (Molisch; Miehe, 1907) to necrobiotic or biotic changes in the plant,[84] Miehe (1930) showed that sterile plant material (intact!), showed hardly any temperature increase.[85] Gaümann was able to show that diseased plant tissue reacted by light (+0.1 °C) temperature increase (potato fever!).[86] Miehe (1930) ascribed the rise in temperature of peas *etc.* in Dewar flasks as observed by Molisch to the action of bacteria. His theory of the temperature increase in hay stacks is microbiological (see p. 216 of his book). Recently mown wet grass, however, may increase in temperature up to 65 °C in a few hours. It seems plausible, therefore, that Schwarz and Laupper (1922, p. 351-365), also in view of extra physiological temperatures (100-300 °C) observed in hay stacks promote a chemical theory. Quite recently Noack (1943) called attention to the role that the so called pyrophoric iron in the leaf plastid may play in this process as a catalyser.[87] It may still be that we should find a multiplicity of causes for temperature elevation. Vital and necrobiotic processes microbiological as well as chemical processes each playing a role.

6.6 Sediments

6.6.1 Introduction

In sediment geology organisms play an important role, if the sediment as in the case of clay is a more or less flocculated suspension, or whether the organism functioned as nuclei of crystallisation in an oversaturated solution (gypsum, calcite) the effect is similar, in as much as the action depends upon the activity of the organism. From sedimentation proper we segregate those phenomena that are dependent upon profound changes in the milieu (shifts of equilibria *etc.*) which have been dealt with at other places. But one form of sedimentation which has a decided biochemical side, has to be mentioned here. Allen (1934) found the influence of algae upon the travertine sedimentation in Mammoth Hot Springs, Yellowstone Park to be negligible. According to van Niel (1932), however, in cooler waters the deposition of milieu could be enhanced by the functional activity of the algae.

83 Verhoop (1940). Miss J.A.D Verhoop married the Delft Professor in Applied Botany, Gerrit Jan van Iterson (1878-1972). According to Baas Becking, Kaplan and More (1960, p. 263).
Verhoop showed convincingly that the oxidation of black iron sulphide to sulphur is an abiological process.
See also Section 7.9.4.

84 In the 1953 manuscript of *Geobiology* Baas Becking described on p. 108 the term necrobiosis:
There is a state, called *necrobiosis* by Beijerinck, where, while organisation is destroyed, the enzymatic activities continue. In the organised cell, enzyme and substrate are kept apart, and their interactions are regulated. In the necrobiotic state, the enzymes freely react with the cell substrate. Molisch, to whom we owe many simple and illuminating experiments, has given a striking example of necrobiosis. When leaves are locally heated, by means of a match, we will see a green plane around the burnt centre. This green area, where both structure and enzymes are destroyed, is the necrotic zone. Around this zone there develops, in many leaves, a dark ring ('Totenring'), showing that here the enzymes were still active, oxidising the phenols to coloured oxyphenoles. This necrobiotic zone is surrounded by normal, biotic, cells.

85 Reference to Miehe (1907), Miehe (1930). In the 1934 edition of *Geobiologie* Baas Becking referred to the research of Miehe in which he was able to isolate a large number of thermophilic organisms. (Chapter IV, p. 33, English edition, 2016).
Hugo Robert Heinrich August Miehe (1875-1932), German botanist in 1909-1910 involved in botanical research in the Botanic Gardens at Buitenzorg, from 1916 to 1932 Professor of Botany at the Agricultural University Berlin.

86 Ernst Albert Gäumann (1893-1963), Swiss botanist and phytopathologist.

87 Reference to Noack (1943). In the 1953 manuscript of *Geobiology* Baas Becking remarked (p. 537):
According to Noack, iron in the necrobiotic cell may catalyse sudden breakdown of organic materials (pyrophoric iron).

Photosynthesis

$$CO_2 + H_2O \rightarrow HCOH + O_2,$$

requires water and it may well be that local decrease of water contents of the silica-charged water may so far change the concentration as to exceed markedly the solubility product of SiO_2.

6.6.2 Supersaturation with gypsum $CaSO_4.2H_2O$; activity of Artemia (Payen et Audouin)[88]

Supersaturation prevented van 't Hoff (1912) to experiment with natural seawater upon the deposition of oceanic salt.[89] When the total concentration of salt is about 11%, $Ca_2SO_4.2H_2O$ should precipitate. As a matter of fact, the solution becomes a rather stable colloidal suspension. Outside the tropics, the suspension is clarified by the action of the brine worm, the phyllopod crustacea *Artemia salina* (Kuenen and Baas Becking, 1938; Warren, Kuenen and Baas Becking, 1938). This small crustacean is a so called 'Strudler' (Lang) it whirls the water towards its mouth and mechanically makes the external milieu pass through its intestinal tract, but the fact remains that a few of these shrimps are able to clear a quart of brine within 2 hours. The gypsum lying in pellets on the bottom of the jar. The effect may also be obtained by means of stable $BaSO_4$ suspensions which shows up better. Practical briners call *Artemia* 'the clearer worm.' An old Italian foreman once told he thought that he couldn't make good salt without *Artemia*. As at that time the older work of Audouin was unknown to him the thing seemed very much like a fairy story.

In the tropics, where *Artemia* does not occur, the gypsum is taken out of the brine by means of sulphate reducing bacteria, which, with the aid of iron, form the insoluble FeS, which impregnates the loamy bottom of the pans as a tough black mud (see Section 9).

6.6.3 Clay suspension

The activity of *Cardium edule*, the heart shell (*Senckenbergiana*, 14, 1932, Schwarz, p. 118. Der tierische Einflusz auf die Meeressedimente),[90] several times already mentioned great activity. *Mytilus* and *Cardium edulis* stabilise the suspended clay in "coproliths", which are rather resistant and form sediments. According to Schwarz this sediment containing much organic matter may be an "inbitumen." None of the low clay region (Wadden) N. of the Dutch and German coast is nothing but recent and sub-fossil coproliths. The animals have to make use of silt.

6.6.4 Sand

Richter, *Natur und Museum* 5, p. 50, (1927), reports on *Sandkorallen Riffe* in den Nordsee. Here a worm *Sabellaria alveolate* L. makes organic coral-like reefs, metres high, in the sand. In Devonian we find fossil quartz like it. It *makes* evil, the worm whirls the sand grains towards its mouth and sticks then together with particles. In this way it builds land. Discovered 1920 the worm was long known, but it makes on a still bottom very irregular tubes, beautiful pictures! *Mytilis edulis* may kill the whole community, (Galaine and Houlbert, *Les Récifs d'Hermelles et l'assèchement de la Baie de Mont Saint Michel, Bull. Soc. Geol. et Min. de Bretagne*, 2, p. 319, 1921) shows that *Sabellaria* reefs form as dam of 3 km wide of small islands 10 km long. A lagoon has been separated. The reefs are 6 m high. Therefore, *Sabellaria* may form regular rock, which only with dynamite or metal nets, may be removed.[91]

6.6.5 Lime deposition

Linné is quoted as having said *"omno calx ex vivo."* This statement expresses modern opinions in a restricted sense. As Wattenberg has shown, natural waters, and in particular seawaters, are, at the surface, oversaturated in calcium carbonate (see also Sections 3.6.2 and 3.13.4). This oversaturation changes with the temperature (diagram in side cover of this book),[92] at the equator the oversaturation may reach 300%. The solution may remain stable, but $CaCO_2$ may crystallise out around active nuclei. The full treatment of the topic would require a large space (this section has to be elaborated considerably later!). We follow the classification of Correns (1939, pp. 193-194) which shall be given with a few additions.

6.6.5.a Intracellular deposition

a) Plant

α) Benthonic algae: (*Chara*, *Corallinines*, *Halomids* etc.).

β) Planktonic algae: (*Coccolithes*).

b) Animals

α) Benthonic: *Corals*, *Sponges*, *Foraminafera*, *Bryozoa*, *Brachiopoda*, *Echinodermata*, *Molluscs*, Worms.

β) Plankton: *Foraminafera*, *Pleropods.*

γ) Nektonic: *Crustacaea.*

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88 Baas Becking referred to 'Payen and Audoin' in the 1934 edition of *Geobiologie* (Chapter X, p. 218, Dutch edition; p. 118 English edition). Jean Victor Audouin (1797-1841), French naturalist Audouin (1836); Payen (1836).
See also Kuenen and Baas Becking (1938), Warren, Kuenen and Baas Becking (1938).
In the 1953 edition of *Geobiology* (p. 565) Baas Becking wrote:
> Already in 1836 Payen and Audouin observed that the brine shrimp (*Artemia salina* L.) could clear stable suspensions of calcium carbonate. The experiments were repeated by the author (Baas Becking, 1931a), using fine and rather stable suspensions of calcium carbonate, calcium sulphate and barium sulphate. Five Artemia cleared 100 cc of a milky white suspension of barium sulphate in twenty four hours, while the controls remained unchanged. Tiny pellets (coproliths) on the bottom of the jar contained the precipitated matter. *Artemia* has a recognised function in temperate solar salt works, where it clears colloidal gypsum from the second reservoirs. For this reason, it is called "clearer worm" by the "briners." The colloid chemistry of this reaction has not been studied. Similar reactions, of much greater geochemical importance, have also been investigated only from the ecological point of view. These reactions are performed by mussels and by heart shells (*Cardium edule* L) in estuaries. Rivers may carry large amounts of clay, silicon and iron oxide in suspension. Hundreds of miles seaward from the deltas of the great tropical rivers one may perceive a sharp demarcation line between the blue ocean water and this white yellow or orange terrigenic suspension.

89 Reference to van 't Hoff (1912). In the 1934 edition of *Geobiologie* (Chapter X, p. 218 Dutch edition; p. 118 English edition), Baas Becking wrote:
> Van 't Hoff described how when seawater is evaporated and the solubility equilibrium of $CaSO_4.2H_2O$ has been exceeded, the compound does not precipitate but remains in suspension.

90 Reference to Schwarz (1932). In the 1953 manuscript of *Geobiology* (p. 566) Baas Becking wrote:
> Schwarz (1932) has called attention to the fact that on the low temperate river flats, mussels and heart shells, continuously flocculate, by means of the ciliated mucous mantle epithelium, these suspensions which are finally deposited as coprolites in the environment. One might say that much of the "new land" near the North Sea is nothing but molluscan coprolite. The process has probably a much wider significance than is yet realised. Active 'pasting' together of sand grains and other particles is a function common to many animals.

91 In the 1953 manuscript of *Geobiology* (p. 566) Baas Becking related:
> Cahune and Houlbert (1921) mention extensive reefs 3 × 10 km of *Sabellaria* near Mt. St. Michel, Brittany. They proved to be extremely solid and could only be removed by dynamite.

Baas Becking referred to 'Cahune' must be 'Galaine': Galaine and Houlbert (1921).

92 The diagram is not on the front and rear cover of this manuscript, so Baas Becking probably referred to Wattenberg.

6.6.5.b Extracellular deposition

a) Green plants, CO_2 assimilation

b) Bacteria, NH_3 Production

Each of these items would require a separate section. *Globigerina* cover 128 × 10^6 km^2, this is 37.1% of the ocean bottom or 25% of the earth's surface. Average $CaCO_3$ 65%.

Pondweed, *Potamogeton lucens* may contribute 5 g $CaCO_3/cm^2$.

Dolomites are also partly biogenic. The chemical $CaCO_3$ deposition at the Bermudas consists of fine needles of aragonite. Calcite is found in coralline. Baas Becking and Irving, 1925 [= 1924] have shown that here the assimilation and the intracellular $CaCO_3$ deposition may be segregated by filtering the excess base (A of Wattenberg [[B] in the formula below]) in the light and in the dark (*Coralline* and *Amphizoa*) (see Fig. 6.7).

The population equation has been simplified by Wattenberg for seawater as $[H^+]$ approximately equals $[OH^-]$ and may therefore be written:[93]

$$[B] = [HCO_3^-] + 2[CO_3^{2-}].$$

Mechanical $CaCO_3$ deposits occur in soils with ascending water circulation (African desert) and also in caves *etc*. where stalagmite formation occurs. Section 6.6.5 should be extended by those mechanical and chemical deposits. Still the overwhelming part belong to the biogenic sediment.

6.7 Summary and conclusions

The school of Rudolf Richter has done much to drive home the idea that the role of the organism in the sediment formation is even larger as we even had expected.[94] And in the cases treated we only have demonstrated the impact of the problem. The influence of the organism upon the composition of soil, hydrosphere, atmosphere and sediment is enormous. There exists an almost classic treatise, written by a young fellow countryman, who unfortunately died when still quite young. Van Dieren (1934), in his *Organogene Dünenbildung*, has claimed that the formation of the sand dunes, both as geomorphological and as geochemical phenomenon, is profoundly influenced by organisms. Beginning with the moving sand in the beach and ending with the podsolised heather, van Dieren (1934) traces the influence of the higher plants on this beautiful sequence of events and convinces us, that even in this unexpected corner the influence of life upon dead material prevails.[95]

93 Baas Becking copied from Correns (1939, p. 187) the Wattenberg equation.

94 Rudolf Richter (1881-1957), one of the most influential geologists of the twentieth century. He founded the Senckenberg Vorschungstelle für Meeresgeologie und Meerespaläontologie (Senckenberg Research Station for Marine Geology and Paleontology) at Wilhelmshaven, Germany, which was subsequently known as Senckenberg am Meer (Senckenberg by the Sea). It was the first institution founded with the specific aim of actively applying the actualistic concepts of Charles Lyell, following the principle "the present is the key to the past", a principle that Baas Becking often quoted. In December 1932, Richter gave a lecture in Leiden, *Bildung künftiger Gesteine in der Gegenwart*, that is referred to in Baas Beckings 1934 edition of *Geobiologie.*

95 Reference to van Dieren (1934). July 12, 1934, J.W. van Dieren defended his thesis in Amsterdam (PhD advisor Prof. Th. J. Stomps). He died on November 14, 1935. See Scheygrond (1936).

7. MUTUAL INFLUENCE

Text box 7.1 – Baas Becking notes made prior to writing the manuscript

"Closed universes", J. Beauverie and S. Monchal. Comptes Rendus, 195 (1932).[1]

Coenobiosis Derx, symbiose, metabiose, pseudometabiosis.

Antagonism, L. v. Luyck.

M. Kiese, Klinische Wochenschrift 22, 505, 1943. Penicillin!

Abraham, Cole and Porter, Raistrick.[2]

Unicellular, all potencies (possibilities) together. Possibilities spread! Is it all redox? Is it all exchange of substances? (See Fig. 7.1).

Maximal to n potencies.

"Autotrophy", antagonism, serology!

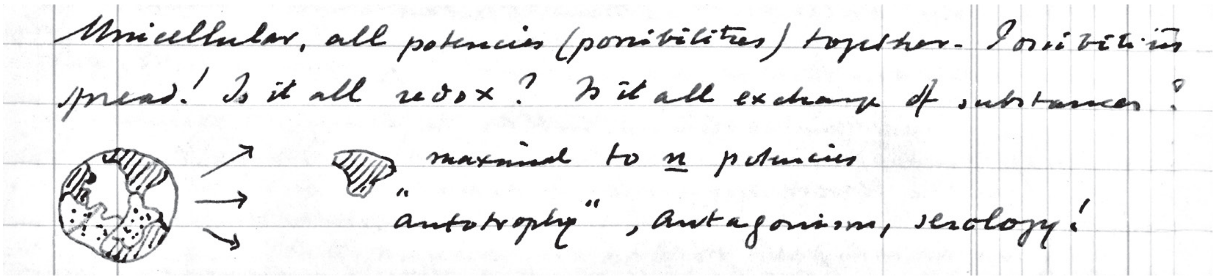

Figure 7.1 Unicellular, all potencies (possibilities) together. Possibilities spread! Is it all redox? Is it all exchange of substances? Maximal to n potencies; "autotrophy", antagonism, serology!

7.1 The Concept of Symbiosis and Antagonism

"Nothing in the world is single" P.A. Shelley.

There ought to be some debate on the question whether the mutual influence of organisms constitutes a section in Geobiology. It certainly has nothing *directly* to do with the direct influence of organisms on the earth's crust. Still mutual influence as will follow from the consideration in this section, is for a larger part chemical influence and there is, therefore, a continuous exchange of substances, not only between inanimate milieu and the organisms, but also between different organisms. This exchange of substances might even, in some cases, directly influence the outward environment. Even when it doesn't apparently influence the milieu this might be due to lacunae in our observations or to inimitable material. The great influence of symbiosis upon geobiology is the *shape* of the biosphere, the form it takes, its natural composition, as the components of a symbiosis and of a biocoenosis form a sort of a symphony orchestra. Organisms are linked up together, as in a gigantic tissue the pattern the warp and the woof. We cannot segregate one actor from this play, one voice from this chorus, without disturbing the ensemble and therefore, when continuing biology here, it should be synbiology.

[In the margin Baas Becking referred to Section 6.3, *Periodic Changes in Chemical Milieu*; Section 7.2.1, Table 7.2a and 7.2b, *Symbiosis*; Fig. 7.14 showing interactions between microorganisms and higher animals.]

Fundamental to any independent existence of a living unit is the power of carbohydrate synthesis, a synthesis which pre-supposes the faculty of carbon dioxide and oxygen. This faculty, as we have seen, is given to the green cell and, moreover to various groups of colourless bacteria. While the green cells use the sunlight as a source of energy, the colourless autotrophs utilise external energy. Carbohydrate synthesis is fundamental to the independent being, but to all living beings should be common the power of plasmic synthesis, at least to a certain degree. We may consider the glucose sugar as a starting point and some here in its metabolites, *e.g.*, the ketoacid[3] consider an amination (according to Martius and Knoop (1937) and Martius (1937) first to organic acid, then to imino acid and finally to amino acid).[4]

These are the first steps of plasmic synthesis. About further stages we know even less. It may be said however that, according to Bergmann, every proteinaceous molecule is

1 Jean Beauverie (1874-1938), French botanist and mycologist. The reference is to Beauverie and Monchal (1932). Beauverie and Monchal demonstrated that in a closed system plants could live in light four years. This seemed possible due to the equilibrium of gasses exchanged by respiration and assimilation by chlorophyl. No fruitation was observed. The growth was dependent on the amount of water available in the system.

2 The references to antibiotic research of A.P. Abraham, M. Cole, C. Porter and R Raistrick, were taken by Baas Becking from Manfred Kiese (1943). *Chemotherapie mit Antibakteriellen Stoffen aus Niederen Pilzen und Bakterien*. Kiese abstracted research about the 'wonder drug' penicillin in the UK and USA from various english language papers on penicillin published in the period 1940-1943. These were unknown to Dutch scientists. Probably Henri Derx informed Baas Becking, when he visited him in the Utrecht prison June 25, 1944, about Kiese's paper from his contacts with the Delft NG and SF [Netherlands Yeast and Spirits Factory] laboratory and the microbiologists Adrianus Petrus Struyk, a graduate from the Kluyver's Delft Technical University Laboratory. [Possibly the name 'L.v. Luyck' in Baas Beckings note is an error for A.P. Struyk.] Struyk produced in 1944 internal reports for the production of the antibacterial substance produced by *Penicillium baculatum*, the 'Dutch penicillin.'
See Burns and Van Dijck (2002), Burns (2005, 2009).

3 Ketoacids are organic compounds that contain a carboxylic acid group and a ketone group.

4 Georg Franz Knoop (1875-1946), German biochemist. Alongside Hans Adolf Krebs and Carl Martius, he clarified the reaction sequence of the citric acid cycle in 1937. Baas Becking referred to Martius and Knoop (1937), who according to Hans A. Krebs in his 1953 Nobel Prize Lecture:

> elucidated the fate of citrate when undergoing oxidation in biological material. Whilst it has long been known that citrate can be oxidated in plants, animals and microorganisms, the intermediary steps remained obscure until Martius and Knoop discovered α-ketoglutarate as a product of citrate oxidation.

built on a recurrent pattern of certain amino acids.[5] The ideas of B.C.P. Jansen, according to whom the pattern is developed on a certain matrix, and, in themselves not only probable, but obvious.[6] The glucose metabolite, as well as the energy necessary for the basic and functional maintenance of life are derived from the glucose molecule. In order that the vital functions are performed normally, this sugar metabolism should not be interfered with. We have therefore, as these fundamental metabolic processes:

1. The anabolism of glucose (*A*),
2. The catabolism of glucose (*K*),
3. The plasmic synthesis (*P*).

A green plant cell is mostly *AKP*, a higher animal *akP* or *aKP*. Now it is obvious that the latter organisms are unable to persist without an organism *AKP* or *AK*. The organism *aKP* is dependent upon cells which are able to synthesise sugar. It has been customary, however, since the days of De Bary, to designate as *symbiosis* another relation between organisms, which might be symbolised as *Ab* (organism 1) and *aB* (organism 2) living together. Each of the components, in themselves, are unable to persist independently – together however they form a "higher unit" *AB*, which is capable of existence. It is a case of "the lame that leads the blind."

It seems, however, arbitrarily, to narrowly delimit the concept of symbiosis and to restrict it to cases of mutual benefit. For at the basis of symbiosis (in the strict sense) and nearly all other interrelations of cells and organisms, there is the process of material, or chemical exchange. We shall have occasion to consider seemingly distantly related processes from under the high viewpoint of symbiosis. It may be seen that in many cases even the rigid definition of De Bary seems, after closer inspection not applicable. The "simple" food relation grass → cow for instance, may well be considered as a classical example of symbiosis. For, in the country of Holland, where forest is climax, meadows are artificial landscapes, caused by grazing animals. [inserted: Barbed wire causes the grassland to become a dense alder thicket within a few years.][7] The grazing animal itself, therefore creates the conditions necessary for the development of his chief food. There would be no grassland without cattle, there would be no cattle without grassland.

Still, the old definition does not pertain to such phenomena as parasitism and to the antagonistic relations between organisms. Neither does it hold for organisms that change the milieu in such a way that others may follow a succedaneous[8] rather than a simultaneous symbiosis (metabiosis, term suggested to me by H.G. Derx).[9] But it seems to express a general rule in the higher animal organism in which, *with increasing morphological differentiation, the chemical power of individual tissues or cells seem to decrease, causing a complicated condition of mutual dependence.* Before we attempt to classify the various phenomena of interdependence, it may be well to describe, anecdotally, certain cases of symbiosis. And we will return to our first example: the cow and the grass. The green cells of the grass blade[10] are able to perform all sorts of inorganic reductions: CO_2→glucose, hexavalent S→bivalent S, nitrate to ammonia. The cells of the grass blade, moreover, are able to break down the formed sugar without external aid, such as aneurin. At least, if we consider such species of grass which are free from mycorrhiza. Furthermore, the cells of the grass blade are able to synthesise, out of the glucose catabolites and ammonia, all amino acids necessary for the formation of the protein molecule.

Most of the photosynthate is stored, however, as cellulose, which forms by far the greatest part of the hay. The cow, at the other hand, is unable to produce sugar from carbon dioxide. It is equally unable to produce glucose from cellulose. It cannot, without external help, metabolise sugar. It needs the phytonic principles, the vitamins.[11] Without the carotene, which is part of its visual purple, it cannot see. And finally, it is only able to synthesise a few amino acids, while most of these "protein building blocks" have to be provided for. With the great morphological differentiation which has led to the organism we call "cow", there has been an increasing chemical importance. A cow + grass is, therefore not even a "closed system" in the sense of Beauverie and Monchal (1932). We need the cellular bacteria and the protozoan population of the stomach in order to decompose celluloses and, perhaps to form the necessary amino acids, enzymes, ergones (vitamins) necessary for the maintenance and the growth of the cow. The inability of the cow to decompose cellulose may be considered as a deficiency in glucose metabolism. The cow, the grass and the microbial flora and fauna of the bovine stomach form a higher, symbiotic entity. The components of such an entity influence our milieu. Nearly every organism is tied to others by many bonds. Nothing in the world is single. [As a note Baas Becking added: It should be specially stated that evolution cannot be conceived as performed by individual species. Due to the interdependence of organisms, evolution should be

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5 Reference to Bergmann (1934).

6 Probably a reference to Barend Coenraad Petrus Jansen (1884-1962), Professor of Physiological Chemistry University Amsterdam.

7 In the 1953 version of *Geobiology* Baas Becking remarked (p. 647):

> For Northwestern Europe forest is climax. Heather protected from sheep will revert to pine, birch forest in Holland. Barbed wire, as a military obstacle protecting certain areas from grazing, will result in the development of the alder. Dunes, protected from man and from rabbits, will show a spontaneous reforestation, the nature of which is dependent upon the calcium carbonate content of the sand. The climax itself is recognised by ecologists to be only a "pause in the eternal change of the vegetation" (Braun Blanquet) and the greatest factor which disturbs the climax is man. The landscape of the largest part of this earth is now definitely "anthropogenic landscape", from grainfields to tea plantations and teak forests. They have their own climax, or rather climaxes. One of them is the weed patch and the other is the desert. Changes in the milieu are of particular interest in the N.W. European series; sea dune, inland dune, heather, where a progressive "decalcification" of the soil, due to leaching by rain, will give rise to various successions often in close proximity to one another. In this 'labour shy' era unwanted successions have given rise to vast 'green deserts.'

Alder thicket is a minerotrophic wetland community dominated by tall shrubs, especially speckled alder (*Alnus incana*).

8 'Succedaneous' means 'coming after of replacing something else'. In the 1953 manuscript Baas Becking used 'successive' instead of 'succedaneous.'

9 Derx (1947) published about metabiosis. Baas Becking, Kaplan and Moore (1960, p. 266) referred to Derx (1947) metabiosis as "an important concept […] As marchin a play, there is a sequence and a constant regrouping of the actors."They described the processes, which "seem, at first glance, only biological. But, apart from the actors, there are also abiological elements in the play. The metabiosis is of a mixed nature."
See for metabiosis Sections 7.6 and 7.8.1.

10 The primary photosynthetic tissue, the palisade mesophyll, is located on the upper side of the blade or lamina of the leaf.

11 'Phytonic' means in botany 'relating to a phyton.' A 'phyton' is the smallest unit of a plant that can grow into an entire plant.

a process in which genetically unrelated but symbiontically related species, should vary simultaneously. Tentatively this concept is named synevolution.][12]

A second example is taken from quite another field of biology (Fig. 7.2). Let circle b in the accompanying figure represent the milieu possibilities of a terrestrial orchid, let us say an *Ophrys*. Quite dependent upon this *Ophrys* is a rust, the milieu of which is depicted by circle a. A digger wasp, showing a high degree of mimicry (Føyn),[13] performs cross pollination. Its milieu boundary c is about identical to that of the orchid. Finally, we know that the endotropic mycorrhiza, the *Corticium* living in the subterranaean parts of the orchid, is not specific, but may enter into symbiontic relations with other plants. Therefore, circle d, denoting the milieu boundary of this *Corticium*, exceeds the others. Here the complex is formed by four components, it is still one of the very single examples of symbiosis.

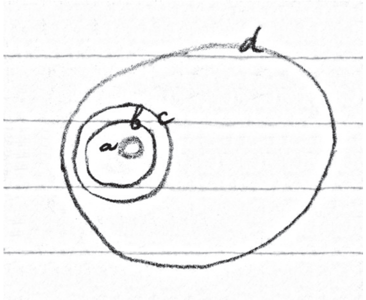


Figure 7.2 Schematic representation of milieu bounderies for **(a)** rust of *Ophrys*, **(b)** *Ophrys*, **(c)** Digger wasp and **(d)** Corticum mycorrhiza.

The deficiency of the functional performance of an organism has to be completed and overcome by another organism or its products. The three large functional groups mentioned: assimilation, dissimilation and plasmic synthesis,

12 See for 'synevolution' Section 5, *Adaptation* and Section 7, *Phylosynthesis*.
In the 1953 version of *Geobiology* Baas Becking further elaborated the concepts under the heading *Synevolution* (p. 677-687). After a quote for A.J. Kluyvers address at the International Congress for Microbiology, Copenhagen July 20-26, 1947, he described his concept of synevolution:

> In his Copenhagen address, 1947, A.J. Kluyver states:
> "One gets the impression that at all levels of evolution one has to do with living substance that is essentially the same. But during the trend of evolution this living substance has started to lose its independence, the losses in synthetic ability increasing with increasing morphological complexity and increasing adaption to a heterotrophic life. Yet the main lines of metabolism have been maintained, the ultimate requirements have remained unchanged. The difference between the various physiological groups of organisms are not to be found in differences in the fundamental constitution of their living substance, but just in the different ways in which the latter originates. Whether an organism itself synthesises the active groups of its enzyme systems, or has to find these groups ready made in its medium is only of secondary importance; the final result being the same in both cases."
> While serology has taught us that the above statement cannot be taken too literally (as there is ample evidence of specific chemical differentiation, particularly on the protein level) Kluyver has given a lucid summary not only of the present status of our knowledge but also, indirectly, of the future task or biology. Suppose that *Neurospora* and other, similar, versatile microbes will yield, in the near future, a 'grand tableau' of biochemistry, genetics has to shift to morphogenetics and (with the help of physiology) to experimental morphology, to the discipline or morphogenesis. For there lies the mystery of the Darwinian phase or evolution. Lotka [*Elements of Physical Biology*], already in 1924, has had a clear conception of this attribute of evolution, when he named one of his chapters *Evolution Conceived as a Redistribution.* He states moreover, (p. 277), that the concept of evolution, to serve us in its full utility, must be applied, not to an individual species, but to groups of species which evolve in mutual interdependence; and, further, to the system as a whole, of which such groups form inseparable part. For to all of the potentialities packed together in a single bacterial cell we have to add (biochemically speaking) almost nothing to arrive at the potentialities of the higher organism, but the great difference lies in the *distribution* of these potentialities over a range of specialised, but correlated, cells. It may be that many chemical possibilities have been lost on the wayside.
> By the term "synevolution" we do not mean that the "completely outfitted" plant cell is, in itself, in origin, a heterosymbiotic creation. Famintzin, in 1907, has claimed that the complete plant cell contained zooxanthellae (plastids), nucleus and protoplasm being an amoeba, while the "microsomes" (mitochondria) represented bacteria. Wallin (1927) is unable to see the difference between intracellular mitochondria and bacteria. No doubt other similar speculations could be traced in the literature. However, as there is not the slightest experimental evidence for these assumptions, it seems that, at the base of the morphological phase of evolution, we should consider a rather large number of different cell types, at different stages of biochemical perfection, some of which gave rise to more differentiated offspring. In this relation the rather unique position of the bacteria, actinomycetes and bluegreens is apparent. They are in some cases, biochemically near "perfect" but the lack of nucleus and (consequently?) the lack of sexual reproduction seems to preclude further morphological development. In more than one. respect they have to be considered as stagnant groups. It would be tempting to compare the phylogenetical, as well as the ontogenetical differentiation with a series of loss mutations as met with in *Neurospora* or in *Chlamydomonas*.
> Certain organisms, apparently, lack a whole packet of genes. It seems trivial to call these relations synevoluistic, however. The ruminants before their appearance, presuppose the existence or grass. If […] right, the grass presupposes the existence of fungi, and fungi cannot live on their own, their existence presupposes an autotroph. Moreover, the cow could not digest the grass without bacteria and, maybe, ciliates. With this example we are right in the middle of synevoluistic thought, and we may proceed to propose the thesis that flowering plants presuppose the presence of insects, and vice versa. This synevolution must have happened in Mesozoic times.

See also Sapp, Carrapiço and Zolotonosoc (2002).
Ivan E. Wallin (1883-1969), American biologist, claimed that mitochondria were symbiotic bacteria. See Sapp (1994, p.46-51 and 113-116); Sapp (2003, p. 240-241).

13 Reference to Bjørn Føyn (1898-1985), Norwegian zoologist, worked as research fellow from 1932 to 1937 with Rolf Nordhagen (1894-1979) at the Bergen Museum. He criticised racial biology as practised in Nazi Germany. During WWII in German occupied Norway he was incarcerated some time in Nazi concentration camps.
Baas Becking repeatedly referred to Føyn. Because his remarks are very personal observations, the references are quoted in full. Baas Becking (1946b) remarked:

> *Ophrys apifera* is an orchid whose flowers, both in shape and scent, imitate the female of a digging [= digger] wasp (Føyn). The imitation is perfect in almost every detail, as photographs show. Even the scent emitted by the female seems to be identical with the odour of the flower. In phylogeny as well as in ontogeny, therefore, we meet the statistically unpredictable, the 'case unique', the element of what we are prone to call 'choice' or else a directing power superimposed upon the otherwise recurrent events which, together we call ontogeny.

In a lecture given in Sydney, Baas Becking (1951b), *Forgotten Biology*, he again used this example.

> There is a small terrestrial orchid, occurring in Marocco and in Western Europe, called *Ophrys apifera*, the bee orchid. A Norwegian botanist, Føyn, a pupil of Nordhagen, has made the observation, now twenty years ago, that only the lower flowers at the stalk set fruit, the upper flowers remaining sterile. It appeared that the oldest flowers, were pollinated by the males of a digger wasp, the wasps being attracted both by visual and olfactory stimuli. After the females of the wasps emerged from the cocoons later in the season, the males lost interest in the flowers and the later flowers remained, therefore unfertilised. The attraction of the males proved to be a sexual attraction, the flower of the *Ophrys* imitating the female digger wasp to such an extent, that, as Føyn convincingly showed by photographs, even the slightest spot on the wings and on the body of the female wasp is reproduced by the orchid. Furthermore, it could be shown that the scent of the orchid, if not identical, is closely related to the scent given off by the female wasp. It seems futile to try to "explain" this mechanism. There are about 30,000 species of orchids, and 5,000 species of digger wasps. The chance that the observed mimesis could be developed by means known to us, even such powerful means as natural selection, is nil. The consequences of this realisation are far reaching. In the first place it gave me the impression that, as a scientist, I am on a big game hunt, equipped with a pea rifle, with toy tools, asked to explain the intricacies of a complicated machine. I might hit a small bird with the pea rifle, I might succeed to unscrew one nut from the complicated machine with my toy wrench but, if I remain honest, I will realise the futility of my efforts.

In the 1953 version of *Geobiology* Baas Becking described the symbiosis between orchids and digger wasps (p. 597):

> The orchid *Ophrys* is pollinated by a digger wasp. The orchid *Cryptostylis* is pollinated by an Ichneumonid. Both orchids are able to secrete a substance identical with, or closely related to, the substance secreted by the respective female wasps, causing a strong taxi in the male. Here the definite organic compound enters into this ontomimetic symbiosis [= symbiosis *via* mimesis of the ontology], but the story is by no means ended, and the phenomenon accounted for. By further specification of this substance, we would be as much in the dark as to the origin of this mechanism, which mechanism, for a long time to come, will defy causal explanation. For, with the specificity of this "attractor substance" we have only touched upon one phase of the problem. *Cryptostylis* flowers crudely resemble, and certain *Ophrid* flowers closely resemble the females, the odour of which they imitate. Here the morphological factors as well as the chemical factors blend to create an entity, and this entity is life itself. And I am not ashamed to use the word 'beauty' in this connection.

the chemical nature of which is obvious, has to be completed by other groups, to wit, sexuality and development. Here also we meet with chemical effectors (Geschlechtsstoffe, Hartmann and Moewus;[14] organisers, Spemann;[15] Needham).[16] The complex of these substances we shall designate by S and D respectively. The group S, however, is in certain cases, not a "conditio sine qua non" for the existence of an organism.

AKPSD is the most complete, and the most completely independent organism, akpsd the most dependent. As said before, the higher animals belong to the latter groups, where concomitant with morphological differentiation and speciation, chemical performance has materially deteriorated. The higher animals need besides its trophon, its caloric food, a great number of ergones. It is quite probable that for the five functional groups mentioned, a large part of the substances needed are synthesised, and provided for, by plants. So, for groups K the B and C vitamins are necessary, for S the vitamin E, while for D the D groups are of paramount importance. Now if we consider a single cell possessing the properties AKPS and D.

This cell gives rise, by division, to various groups of tissues, deficient in one or more of these functions. The organism, while still being as a higher unit, capable of all these functions, represents a consortium of specialised cells. Such a consortium we will call an autosymbiosis. If the consortium is built up of various species, we may speak of heterosymbiosis.[17] Gamosymbiosis is the sexual relation between individuals of the same kind, and therefore a form of autosymbiosis. Sociosymbiosis, the formation of a socium contains both auto- and heterosymbiotic relations. Saprophytism and parasitism also fulfil the requirements as belong to the wider concept of symbiosis. A parasite autosymbiosis is the formation of the embryo within the mother organism. Saprophytism, in most cases belongs to the metabiosis or succedaneous symbiosis. In order to oversee the difficulty of a "contradiction in terminis" the word coenobiosis may be used to cover both the simultaneous (symbiosis) as well as the succedaneous (metabiosis).

The expression of coenobiosis also termed *biocoenosis*, a community of various organisms which are more or less in mutual equilibrium with each other and with their internal milieu. It stands to reason that the concept of symbiosis lies at the basis of the knowledge of a biocoenosis and that the chemical and physical process as well. A biocoenosis leave their imprint upon the biosphere. The knowledge of the mutual relations between organisms is therefore of paramount importance to the geobiologist. At the end of this section various biocoenosis shall be, as far as possible, analysed.

We may inquire a little further into the potencies of organisms. A simplified scheme is given below (Fig. 7.3a). Carbon dioxide assimilation [anabolism] is represented over an intermediary *A*. Dissimulation [catabolism] over an intermediary *C*. Cellulose formation and breakdown also represented. Further reduction of nitrate and sulphate, formation of amino acid and formation of protein.

14 Max Hartmann (1876-1962), German biologist. Author of studies about sexuality such as: Hartman (1940). Hartmann was the PhD advisor of Franz Moewus (1908-1959), the controversial German scientist.
The investigations on sex hormones in the green algae *Chlamydomonas* carried out by Moewus, Kuhn and collaborators at Heidelberg have been extensively reviewed and all attempts to repeat critical features of the work failed. See Sapp (1990); Deichman (2001, p. 329-336).
In the 1953 manuscript of *Geobiology* Baas Becking referred on several pages to the work of Moewus. In the 1953 manuscript of *Geobiology* he referred to Moewus (p. 106-107). Baas Becking met Franz Moewus when Moewus and his wife Liselotte were working as Timbrol Fellows in the Botany Department of Sydney University (November 1951-1953):

> If one has had the privilege, like the author, to see Frans Moewus performing *Chlamydomonas*, one is amazed at the complexity of the behaviour of these unicellular algae and of the physical and chemical factors controlling their various coordination's with the environment. For these, and similar, so called "simple" organisms the rules governing the behaviour, growth and development are already beyond us. Even if we could account for all of the processes of differentiation and of coordination in the development of the higher organism, we would be still be unable to integrate them into a rational concept of the *organism as a whole*, in tune with its environment. And after this riddle there are other mysteries, those of relationship and of descent. The last century has given us the wholehearted cooperation of chemists, physicists, and mathematicians. the mere fact that these workers, so highly successful in their more accessible fields have failed to point out to us even where the riddle lies, has convinced the author that the central problem of life, the understanding of the vital state, is still outside the present realm of the more exact sciences. This does not mean that advances in biology, especially in biochemistry have not been commensurate with those in the more exact sciences, but only that the problem of life is so complex.

The 'organism as a whole' concept is a reference to Smuts (1926), *Holism and Evolution*. See also Section 1.4.

15 Hans Spemann (1869-1941), German embryologist. The Spemann-Mangold organiser, also known as the Spemann organiser, is a cluster of cells in the developing embryo of an amphibian that induces development of the central nervous system. Hilde Mangold (1898-1924) was a PhD candidate who conducted the organiser experiment in 1921 under the direction of her graduate advisor, Hans Spemann, at the University of Freiburg in Freiburg, German. Her thesis was published in 1924. Without her consent Spemann had added his name as first author. The discovery of the Spemann-Mangold organiser introduced the concept of induction in embryonic development. On September 4, 1924, Mangold died of severe burns caused from a kitchen explosion in her apartment. Therefore, she did not share the Nobel Prize in Physiology or Medicine awarded to Spemann in 1935.
In the 1953 version of *Geobiology* Baas Becking remarked (p. 19):

> We know next to nothing about morphogenesis itself, but the work of Needham (1931) establishes the main outlines of its chemical basis. Already in 1921 Spemann and, in 1933 Brachet [Belgian biochemist Jean Louis Auguste Brachet, 1909-1988] adumbrated the possible chemical nature of the "organising principle" in ontogeny. Since then, many facts have come to light which have clearly demonstrated the role of specific hormones, enzymes and inhibitors in the development of the organism. It should be stated that already Haberlandt, in his *Physiologische Pflanzenanatomie* had foreseen this possibility.

See Spemann and Mangold (1924), De Robertis (2009), Sapp (1997), Sapp (2003, p. 176-177).

16 Reference to Joseph Needham (1900-1995), British biochemist. Baas Becking referred to his three volume *Chemical Embryology* (Needham, 1931).

17 In the 1953 manuscript of *Geobiology* Baas Becking discussed 'Heterosymbiosis' as a complex of binary combinations between organisms (p. 610-611).

> The binary relations between sixteen groups of organisms, yielding 16 x 15/ 2 or 120 combinations. As the species inside each group will show mutual symbiotic relations at least 136 groups of binary combinations are possible. […] It would require a comprehensive study of the widely scattered literature on subjects as field biology, ethology and ecology to increase the number of relations materially.

In a note he remarked:

> Relations between molecules, as governed by mass laws, chemical kinetics (with the inclusion of catalysis) are, of course, much better understood than relations between organisms. The same pertains to celestial bodies. There is a curious analogue, however, with the latter; in the attempts at a mathematical analysis of the relations between two organisms, already considerable difficulty has been encountered (Lotka, 1924), while a three component system gives rise to very complicated relations indeed. Here we meet with an analogue, of the 'three body problem' of the astronomer. Pluricomponent systems have proved, as yet, little amenable to mathematical analysis.

Scheme Coenobiosis:

Coenobiosis See also Tables 7.2a and 7.2b	**Symbiosis**	Destructive		
		Exploitative	Autosymbiosis	Embryology
			Heterosymbiosis	Parasitism
		Mutualistic	Autosymbiosis	Gamosymbiosis Histosymbiosis
			Heterosymbiosis	= Symbiosis s.s.
		Independant	Heterosymbiosis	= Mimicry
	Metabiosis	(= succedaneous symbiosis)		
	Antagonism*			

* "penicillin" and "oxaline",[18] modern natural bacteroides and probably nothing but "defense substances" of fungi. Such defence substances we also find in the seeds of *Capparis* and *Tropaeolum* and within the glands of *Humulus* fruits (all bacterial).

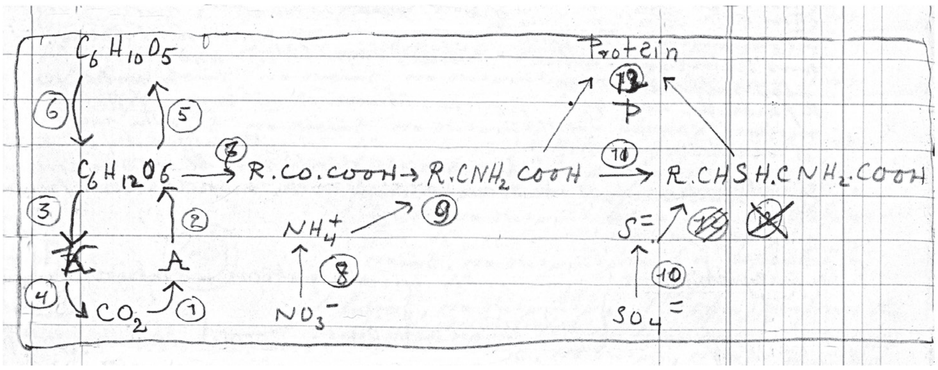


Figure 7.3a Scheme formation of protein. See Table 7.1 for an explanation of the steps in the formation process of proteins.

Table 7.1 Steps in protein formation in Figure 7.3.

Step	Specification of step in protein formation
1	CO_2 assimilation, 1st stage
2	CO_2 assimilation, 2nd stage
3	Glucose respiration, 1st stage
4	Glucose respiration, 2nd stage
5	Cellulose formation
6	Cellulose breakdown
7	Formation of keto-acids
8	Reduction of nitrate
9	Formation of amino acids
10	Reduction of sulphate
11	Formation of cystine
12	Protein synthesis

A complete autotroph may be represented by Figure 7.3b, that is the abstracted scheme from Figure 7.3a.

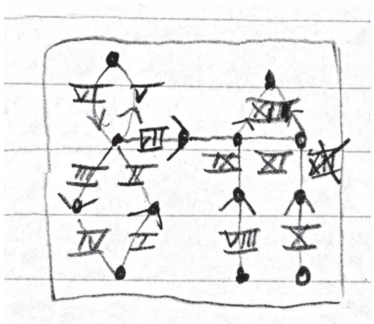


Figure 7.3b Abstracted scheme of Figure 7.3a, formation of protein. The steps are numbered by Arabic numerals.

Now Quispel (1943 and 1946) proved that the lichen *Xanthoria* has gonidia which cannot perform photosynthesis without a diënol. This alga is therefore (1) or (2). The fungus needs aneurine, is therefore (4). They are therefore as follows (roman numerals mean "capable", arabic numerals is "incapable"):

Gonidia	1	II	III	IV	5	6	7	8	9	10	11	12
Fungus	I	2	III	4	5	6	7	VIII	9	X	11	12

18 A reference to an antibiotic oxalicum product of Penicillium oxalicum. Penicillium oxalicum produces secalonic acid D, chitinase, oxalic acid, oxaline and β N-acetylglucosaminidase and occurs widespread in food and tropical commodities. This fungus could be used against soil borne diseases like downy mildew of tomatoes. Penicillin and oxaline were at the moment Baas Becking wrote this text not available as medicines. Production of penicillin started when the US entered WW II. During the War, penicillin made a major difference in the number of deaths and amputations caused by infected wounds among Allied forces, saving an estimated 12 %–15 % of lives.
See also Baas Becking's annotations at the beginning of Section 7 about penicillin research during WWII in Germany and The Netherlands.

The cow, the grass and the bacteria:

Cow	1	2	III	IV	5	6	VII	8	IX	10	11	XII
Bacteria	I	2	III	IV	5	VI	VII	VIII	IX	X	XI	XII
Grass	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII

See for this case Section 7.4.4, *Phylosymbiosis*.

7.2 Ergones

Text box 7.2 – Baas Becking notes made prior to writing the manuscript

Ergones. (v. Euler, *Arch. Chem. Mineral. Geol. Bd*. 11a, 12, 1934).[19]

G. Harmsen in Aerob. Cell decomposition finds many "bios"-like substances, "pure cultures are often not even viable on the ordinary synthetic media".[20] *Prepared* media.

Die Wuchstoffe in der Mikrobiologie. A. Janke.[21]

7.2.1 Introduction

The organic counterpart of the minimum substance is the "Wirkstoff", the ergone, the nutrilite, or by what other names we want to call an ever increasing host of organic substances, each of them claiming to be necessary for 'something.' It is beautiful to work with an ergone, as one obtains specific effect from a specific substance. Pharmacology does this too and it has been, therefore, happy with it. But if biology be reduced to a host of little bottles full of ergones each of them 'doing something', while we have not the faintest inkling of the "why", there is a great danger in the modern pharmacological riot which seems to reign in biology.

Let us recall the examination at the end of *Le Malade Imaginaire* of Molière. Here the board asks why opium puts a fellow to sleep: the considerate answer that there is a specific virtue in it, "Bene, bene, respondere."[22] We feel as helpless as the modern medic who applies the new patent residues with their beautiful names. Apart from the dienoles and vitamin A, I have not the faintest idea how an ergone or enzyme or serum, or hormone, works. It works and we know that is the most important. For it may be that, what we call "neutral influence" is directly the work of ergones and that this entire living nature is linked together by them like a gigantic organism. The question may even be put, whether there is an intrinsic difference between ergone of the enzyme, hormones, vitamins and the like.

When we know more about the specific function of ergones, the 'pattern' of each symbiosis may be written down. So, the classical case of Schöpfer and Jung (1937) see 7.5.19. Unfortunately, chemical analysis has not proceeded far enough to allow us to carry the matter further. H.G. Derx, 15-8-44 in litteris.[23]

The excrements of all kinds of animals are particularly rich in ergones. *Haematococcus pluviatilis* grows best on cow manure. We think about the work of Thaxter on *Myxobacteriaceae*,[24] which he found on all sorts of dung (rat, rabbit, *etc*.) and several genera of fungi, named in Saccardo (in finis bovis *etc*.) (strumania).[25] It is interesting to think that the organic substances, after passing through the intestinal tract should not only be assimilated but that, in their stead, microbial as well as "host" ergones should appear in the excrement. *Asteromonas gracilis* Atari and *Brachiomonas* both *Polyblepharids*, occur in salt pools with bird excrement. Thinking of the work of Darwin on the earth worm one wonders what this animal contributes in the way of ergones! Bassalik (1913) isolated the bacterium *Pseudomonas extorquence* from its gut, a bacterium able to decompose oxalic acid.[26] 'Coprology' may be a promising science indeed! (See for this Section 3.12.3a, *Humus*). Suggested experimentation with excrements of a great variety of animals, sterile filtrates and tried in pure cultures of a number of standard organisms.

7.2.2 Carotenoid

Vitamin A, reaction Carr and Price (1926) ($SbCl_3$).[27]
½ molecule of γ carotene.

[Baas Becking inserted Fig. 7.4.]

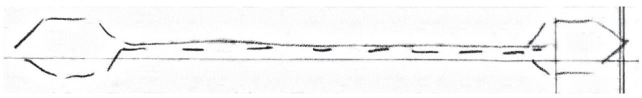


Figure 7.4 Rough sketch of carotene molecule.

Provitamin A, Vitamin A, anti-endophthalmitis[28] (carotene part of the visual purple).

19 Baas Becking referred to Hans Karl August Simon von Euler-Chelpin (1873-1964), German born Swedish biochemist, won the 1929 Nobel Prize in Chemistry for research on alcoholic fermentation of carbohydrates and the role of enzymes. However, the work on "ergones" was done by his son Ulf Svante von Euler (1905-1983), Swedish physiologist and pharmacologist, who received 1970 Nobel Prize in Physiology and Medicine for his work on neurotransmitters.

20 Reference to Harmsen (1946). The research was finished in 1939, but published after WWII. See also Section 3.9.

21 Possibly a reference to Janke and Sorgo (1939).

22 Baas Becking referred to the act of Molière's *Le Malade Imaginaire* (1673) where there is an exchange between the dancing doctors speaking in a fake Latin language ("B.B.'s 'Board'") and the chorus:
Le Premier Docteur : Domandabo causam et rationem quare Opium facit dormire.
Le Bachelier [the Bachelor] : […] quia est in eo virtus dormitive, cujus est natura sensus assoupire.
Chorus: Bene, bene, bene, bene respondere: Dignus, dignus est entrare in notro docto corpore.

23 'In litteris' means 'In letters". Apparently, Henry Derx wrote a letter to Baas Becking when he was in the Utrecht prison. July 25, 1944, he visited him in prison together with T. Niekerk-Blom. They were allowed to speak with him for 25 minutes and gave him two books at that time. Source: NIOD 214 nr 33. Apparently, Baas Becking and Derx discussed the subject of 'symbiosis' during this visit, which Derx in his letter [not retraced] further explained.

24 Roland Thaxter (1858-1932), American mycologist, renowned for his contribution to the insect parasitic fungi. Thaxter wrote in the 1890s several studies about *Myxobacteriaceae* in the *Botanical Gazette*, *e.g.*, *On the Myxobacteriaceae, a New Order of Schizomycetes*.

25 Reference to Pier Andrea Saccardo (1845-1920), Italian botanist and mycologist. Baas Becking quotes from Saccardo's *Sylloge Fungorum omnium Hucusque Cognitorum*.

26 See for Bassalik also Section 7.1.

27 Reference to Carr and Price (1926). The Carr-Price reaction was employed in testing biological materials for vitamin A. The amount of blue colour produced by the reaction of vitamin A with a chloroform solution of antimony trichloride ($SbCl_3$) is proportional to the amount of vitamin A present.

28 Endophthalmitis means bacterial or fungal infection inside the eye involving the vitreous and/or aqueous humors.

7.2.3 Vitamin B complex, aneurine, nicotinic acid

Goldberger 'black tongue', 'pellagra' factor.[29]

[Baas Becking inserted Fig. 7.5.]

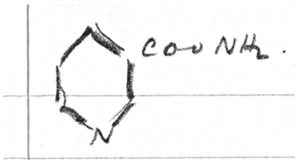


Figure 7.5 The structure is not clear but is probably meant to represent nicotinic acid.

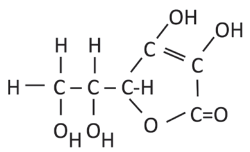
Aneurin, Co carboxylase, thiasole.

7.2.4 Bios complex biotin, pantothenic acid, inositol[30]

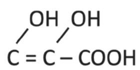
E. Wildiers found already in 1901 that few yeast cells hardly served as inoculum, but many cells gave good result (controversy Liebig/Pasteur).[31]

7.2.5 Ascorbic acid and dienole

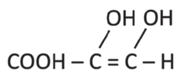
Ascorbic acid $C_6H_6O_8$,



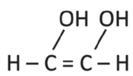
Reductive *acid* (von Euler),



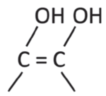
dioxymalic acid,



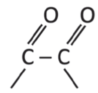
reduction,



are all characterised both possession of the dienole group,



which may be oxidised,



all these substances have an abnormally low redox potential. Ascorbic acid was discovered by Szent-Gyögyi, it is now industrially made from sorbate.[32] Dioxymaleic acid is more out tartanic acid with H_2O_2. In glucose solutions sterilised at pH > 8.0 sometimes appears which has an unstable Pb salt. Reductive acid was also discovered by v. Euler in pectin substances.[33] They all react with di-ether phenols indophenole, but very slowly, with methylene blue (after illumination). Ascorbic acid is the ascorbic vitamin. The ascorbic acid water as a mediator in oxidation. Dioxymaleic acid, moreover, seems to destroy oxydases.

Ascorbic acid is present in most green plants. Very much in paprika, green peas, strawberries, asparagus and cauliflower stem. Giroud claims that it accumulates in the green plastids but the reaction used by him ($AgNO_3$ in light) is hardly to be called specific.[34] However, Quispel (1943) proved that certain lichen gonidia could only perform photosynthesis when ascorbic (or for that matter) dioxymaleic acid were present (in a hydrogen atmosphere). It may be that in plants the dienoles function as oxidation regulators and, moreover, as a kind of photosynthesis 'hormone'.[35]

7.2.6 Steroles

Vitamin D1 and D7 anthraquinone derivates. Closely related toad poison, Arginea [*Micropsalliota arginea*] and Digitalis glycoside (Stoll, 1937),[36] sex hormones (Butenandt, Ružička) and carcinogenic substances.[37] It is claimed that the animal sterols are synthesised by the animal cell (cysterol vs. phytosterole). This seems improbable.

See Nicolai in *Vakbl. v. Biologen* (1943).

29 Reference to Dr. Joseph Goldberger (1874-1929), Hungarian American epidemiologist who studied the pellagra and demonstrated that pellagra was associated with diets deficient in animal proteins. Pellagra is a disease caused by a lack of vitamin B3. Symptoms include inflamed skin, diarrhoea, dementia and sores in the mouth. The disease is manifested in dogs as 'black tongue.' Baas Becking's son Jan Mattias Baas Becking died of pellagra in 1945 in the Japanese Mariso prisoner camp at south of Macassar (Sulawesi). The Mariso camp housed prisoners of war from June 1944 to August 16, 1945. In that period, 330 people were killed in the camp (out of 1,500 camp residents).

30 Vitamin B complex, includes eight vitamins soluble in water.

31 Wildiers (1901) discovered that yeast required a special growth factor, which he named "bios". It proved to be a mixture of essential factors, one of which was biotin. Baas Becking referred to the Liebig-Pasteur dispute on the processes and causes of fermentation. Pasteur supported the idea that fermentation was a biological process, Von Liebig supported the idea that fermentation was a chemical process, discrediting the idea that fermentation could occur due to microscopic organisms. Eduard Büchner uncovered in 1897 the nature of alcoholic fermentation by his discovery that yeasts produce an enzyme that catalyses the chemical fermentation process both inside and outside cells.
Reference to Eduard Büchner (1860-1917), German chemist, winner of the Nobel Prize in Chemistry in 1907. The classical treatises are Büchner (1897a and 1897b).

32 Baas Becking referred to the Reichstein-Grüssner process designed for vitamin C production on industrial scale in 1933. D sorbitol is converted to L ascorbic acid using a fermentation step (bioconversion of D sorbitol to L sorbose by *Gluconobacter oxydans*) and several chemical steps (from L sorbose to L ascorbic acid).

33 In this section on *Ascorbic acid and Dienol*, Baas Becking referred to H. von Euler-Chelpin's work on oxidation and reduction of ascorbic acid.

34 Reference to Giroud (1938).

35 Reference to PhD thesis A. Quispel (1943, p. 478-479).

36 Stoll (1937. The cardiac glycosides are a group of plant materials arbitrarily so named because of their specific "digitalis-like" effect on the heart muscle. Chemically, the cardiac glycosides are steroid derivates.

37 Reference to Adolf Friedrich Johann Butenandt (1903-1995), German biochemist who was awarded Nobel Prize in Chemistry in 1939 for "his work on sex hormones." He initially rejected the award in accordance with government policy, but accepted it in 1949. Butenandt's involvement with the Nazi regime and various themes of research led to criticism after the war, and even after his death the exact nature of his political orientation during the Nazi era has never been fully resolved.
See Trunk (2006), Deichmann (1996, 2001).
Also reference to Leopold Ružička (1887-1976), a Croatian-Swiss scientist and joint winner of the 1939 Nobel Prize in Chemistry "for his work on polymethylenes and higher terpenes […] including the first chemical synthesis of male sex hormones." From 1927 till 1930 he occupied the Chair of Organic Chemistry at Utrecht University.

7.2.7 Auxins

Indolyt acetic acid and butynic acid, the heteroauxines = rhizopon.[38] See Koningsberger, *Leerboek der Algemeene Plantkunde* (1943).

Since Went's classical work in 1927,[39] and the brilliant chemical researches of Kögl, we know of plant hormones that are able to make cellulose walls plastic in that they may be extended by longer pressure until new molecules of cellulose be laid in between the old (internode sections). Higher plants produce the auxins proper, microbes and bluegreens also heteroauxine. Auxine may be inactivated by light (lumiauxin).[40]

7.2.8 Phyllochitins

Vitamin E contains, apart from the chinons a long phytol chain, identical to that met with in the chlorophyll molecule. Evans proved the presence of the fertility vitamin in wheat germ 1929.[41]

See also 5.11.1, *Anaerobiosis, Aerobiosis*; 6.4.2.a, *The Composition of the Atmosphere.*

7.2.9 Other vitamins and possible ergones

Vitamin F (Burr and Burr, 1929),[42] and a skin vitamin, the absence of which in the food causes "plagues" to appear in rats. It has been shown that the substance is probably linoleic or linoleic acid. A rather large quantity is needed (identity with fearon acid!).[43]

7.2.10 Summary and conclusions

See Figure 1.1, Figure 7.14 and Scheme Coenobiosis in Section 7.1.

Table 7.2a Symbiosis.

Symbiosis[44]									
	histo	gamo	ortho	KTENOSIS	phago 4		gamo	oiko	H
A	1	2	3				5	6	E
U	histo	gamo	ortho	PARASITISM	ecto	endo	gamo	oiko	T
T	7	8	9		10	11	12	13	E
O	histo	gamo	ortho	HELOTISM	ecto	endo	gamo	oiko	R
B	14	15	16		17	18	19	20	O
I	histo	gamo	ortho	MUTUALISM	ecto	endo	gamo	oiko	B
O	21	22	23		24	25	26	27	I
S	NECROSYMBIOSIS			SAPROBISM	ecto	endo		oiko	O
I	28				29	30		31	S
S	Ontogeny			METABIOSIS	successions				I
	32				33				S

38 The heteroauxine is indole-3-acetic acid (IAA), was isolated in 1934 by Fritz Kögl (1897-1959) and co-workers from human urine; they named the auxin 'hetero-auxin.' In the early 1930 Kögl and co-workers had isolated non-indole auxins: auxin a (auxentriolic acid) and auxin b (auxenolic acid) also from human urine, which they considered as the growth hormone auxin in plants. In the above text Baas Becking therefore characterised these substances as the 'auxins proper.' Nowadays however, IAA is accepted as the plant growth auxin, because auxin a and auxin b were found to be not natural plant products and IAA has since been isolated from numerous plant species and has shown to be ubiquitous in the plant kingdom. The auxin a and auxin b issue is nowadays considered to be a fake of Kögl's assistant Hanni Erxleben (1903-2001), although Kögl was possibly also implied.
See Haissig and Davis (1994), Arteca (1995, p. 1-12, *Discovery of Plant Growth Substances*); Deichmann (2001, p. 339-342), Wildman (1997).
Rhizopon A tablets containing hetero-auxine were produced in the 1930s by the N.V. Amsterdamsche Chininefebriek and used in oculation in plantculture.

39 Reference to PhD thesis Went (1928).

40 Reference to Koningsberger and Verkaaik (1938).

41 Reference to Herbert McLean Evans (1882-1971), who in 1922 at Berkeley along with Katharine Scott Bishop (1889-1975) co-discovered vitamin E. (Evans and Bishop, 1922). They found that the dietary factor, essential for reproduction in rats, is fat soluble and present in green leaves (lettuce), and occurs in special high concentration in wheat germ.

42 Reference to the work of George Oswald Burr and Mildred Burr, who discovered in meticulous analysis of rats fed special diets that fatty acids were critical to health. If fatty acids were missing in the diet, a deficiency syndrome ensued that often led to death. The Burrs identified linoleic acid as an essential fatty acid.

43 Reference to William Robert Fearon (1892-1959), Irish politician and Professor of Biochemistry at the University of Dublin. He published about biochemical colour tests. In 1925 about *Colour Reactions Associated with Vitamin A*.

44 In The 1953 manuscript of *Geobiology* (Baas Becking, 1953a, p. 592 and 593), Baas Becking used the following classification of symbiosis, which is a further enlarged version compared with that in the 1944 manuscript of *Geobiology*:
KTENOSIS. The killing of the other, for food, in defence, or for other reasons.
ANTAGONISM. The exertion of an adverse influence, which need not result in another's death.
PARASITISM. To subsist upon another without the primary object of killing.
HELOTISM. To exploit another.
MUTUALISM. To benefit by another's activities.
COMMENSALISM. "To feed at a common trough".
SAPROBISM. To subsist on the refuse of others.
MIMISIS. To imitate another, or an inanimate object.
METABIOSIS. The succession of organisms.
The scale of complexities of the substrate could be stated as follows:
CYTOSYMBIOSIS. example; phagocytosis.
HISTOSYMBIOSIS. "organiser", hormones in correlative metabolism.
GAMOSYMBIOSIS. sex substances in flagellates, ferns, flowers, animals
ONTOSYMBIOSIS. this is the relation between individuals. Example; domestic plants, bacteria in the rumen of the cow.
OIKOSYMBIOSIS. relations of individuals in a community.

Table 7.2b Examples of Symbiosis.

	Examples				
1	Osteoclasts	12		23	Herd, pack
2	Males of spiders	13	L[epiotaceae fungi] in ant's nest. Galls!	24	Ectosymbiosis s.s.
3	Drones	14	Root tissue in plants	25	Endosymbiosis s.s.
4	Food relations	15		26	Flower biology
5		16	Incubation of egg parental care	27	Dispersal of seeds
6	Defence of herd collecting food	17		28	e.g., excretion derivates in *Chlamydomonas*
7	Embryos	18		29	Saprophytes s.s.
8	Males of certain worms	19	Fly trap flowers (*Aldrovanda*)	30	Scavengers or true symbionts
9	Suckling	20	Slaves, fungus garden seed dispersal of ants	31	
10	Ectoparasites	21	Hormonal correlation	32	Organisers
11	Endoparasites	22	Zygote formation	33	Succedeanous cultures

Let us consider a higher plant in its symbiotic relations (see Tables 7.2a and 7.2b).

- Of ktenosis we only find *phagoktenosis* (4) in insectivorous plants.
- *Oiko-ktenosis* here (6) maybe at the basis of the substances like *penicillin* or *oxaline* and the germination preventing substances of Fröschel. For these, and allied matters see Funke (1942).[45]
- *Histo-parasitism* we find in the embryo (7). *Gamo-parasitism* is typical for all higher plants, as the sexual cells both few on surrounding tissue, especially the pollen tube. (8).
- *Ecto-* and *endoparasites* (10,11) we find galore, wasps and plant lice may cause galls, to them a case of *oikoparasitism* (13). In the differentiated higher plant, there is *histo-helotism* (*e.g.,* host tissue) (14), while the fly trap flower, like *Aristolochia*, actually exploit insects (*gamo-helotism* 19).
- Seeds with spines *etc.*, promote the *oiko-helotism* (20) by which animals disperse the seed without water! *Histo-mutualism* describes further the chemical correlation on the plant body (21), while the sexual act is seen as *gamo-mutualism* (22).
- The growing together of plants of the same species may be an expression of *ortho-mutualism* (23).
- *Ecto-* (24) and *endomutualism* comprises the classical cases of symbiosis, while the so called flower biology is named here as *gamo-mutualism*.
- Seed dispersal when the seed is eatable or eatable in part (ornitho-chorisis, myrmica-chorisis),[46] may be called *oiko-mutualism* (27).
- Plants may, on dying give of useful substances (28) to the species (*necro-symbiosis* 28), they may live a saprophytic life (*ecto-saprobiosis* 29), while their *ontogeny* (32) and the *succession* of species inwards and external (33) are cases of metabiosis.
- In the complex of symbiosis plants already represent more than twenty cases of *sapro-biosis*!

7.3 Physical Factors

7.3.1 Introduction

[Baas Becking left this section blank.]

7.3.2 Temperature series according to Miehe[47]

[Baas Becking left this section blank.]

7.3.3 Epiphytes

[Baas Becking left this section blank.]

7.3.4 Epizoa

[Baas Becking left this section blank.]

7.3.5 Summary and conclusions

[Baas Becking left this section blank.]

7.4 Autosymbiosis

7.4.1 Introduction

Increase in specialisation when traveling upwards in the evolutionary scale, from bacteria *via* algae and mosses to ferns and further to higher plants, we find an increasing degree of specialisation of the individual cell, capable to perform all functions.

45 Reference to Fröschel and Funke (1939), Funke (1942).
46 Chorism or chorisis is multiplication or dispersal of botanical elements, in the text meant by birds and by ants.
47 Reference to Miehe (1907) and Miehe (1930), see also Section 6.5.

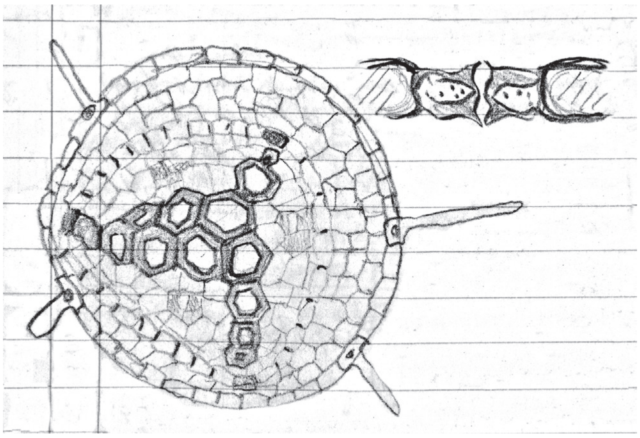


Figure 7.6 Cross section of root of higher plant and section of stoma of a leaf.

The cell in Figure 7.6 shows a cross section of a root of a higher plant and a section through the stoma of a leaf, to show differentiation.

Table 7.3 Number of cell types in the plant kingdom, animal kingdom not filled in.

	Specialisation	
Bacteria	2	Protozoa
Bluegreens	4	
Green algae	8	
Brown algae	8	
Red algae	16	
Mosses	32	
Pteridophytes	64	
Phanerogams	128	Mammals

Table 7.3 shows, approximately the number of cell types while ascending the evolution ladder in the plant kingdom. For the animals a similar series could be built up. Now it is impossible to take a cell of a root parenchyma and raise a whole plant out of it. Only the epidermal cell of *e.g.*, the *Begonia* has kept its "prospective potency" (Hartsema, 1926) and may generate a whole plant. Most of the cells are too far specialised to perform this feat. The entire plant body is able to perform that what the green unicellular did by itself. Morphological differentiation has decreased the chemical potentiality, leaving the total potency the same or even increased. From this it follows that autosymbiosis should be considered as essentially biochemical in nature, and that development and differentiation go hand in hand with continuous and synchronous exchange of ergones.[48]

7.4.2 Histosymbiosis and ontogeny

J. Needham, chemical embryology, Spemann (organic concept).[49]

7.4.2.a Tissues

Most tissue cultures of animal cells, revert, in the long run, to connective tissue, Differentiation 'goes back', retrogrades; there is de-differentiation and differentiation (Gaillard).[50] Tissue cultures from chicken embryos have shown that differentiation of, let us say bone tissue, only occurs when juice has been added from a chicken embryo of the age in which it forms bone. This shows that differentiation is induced by certain very specific substances. The same holds for thyroid, parathyroid.[51] This the first direct proof of the existence of 'organisers' throughout the entire developmental cycle. It seems not too far fetched to claim that throughout the life of organisms, in removal and in breakdown of tissue, such like substances should be continually active.

7.4.2.b Hormones as maintenance

Endocrines, when synthesised by the organism itself, should be considered in the same way as the mycetomes (Buchner, 1921) of insects.[52] Here we have islands of tissue, the cells of which are microbes or filled with microbes, which cells secrete substances necessary for the maintenance of the organism and which substances are transported by body fluids ('*ορραω*' [?] I carry a message).[53] It is a fanciful, but not entirely creative, thought to consider the endocrine glands of higher animals as evoluated mycetomes. It is of course known, how all the messengers carry ergones, as secretin, adrenaline, choline, thyroxin, progestron, androsterone, pituitrine *etc*. Again, here there is quite a mass of ergones! And this increase in the number of these endo-ergones in evolution goes hand in hand with morphological differentiations. The more highly differentiated, the more dependent the cell becomes upon its environment.

48 In the 1953 version of *Geobiology* Baas Becking described autosymbiosis as follows (p. 156-158):

Modern cytology has painted the fascinating and complex picture of the continuity of the innermost, particulate expression of the specific individuality, localised in the nucleo-proteins in the confines of the nucleus. This is, in the space-time continuum, the "germ track", the "Keimbahn" of the older authors. Sexual differentiation, a specific form of symbiosis (which may be called gamosymbiosis) we know to be a powerful agent in evolution.

With this symbiosis, resulting from differentiation within the organism (an autosymbiosis) the possibility for an endless variation in pattern became possible. The offspring of a single cell gives rise to an organism, the cells of which are mutually dependent. [Baas Becking inserted the remark: like the halt and the blind.] Cells became specialised and took over single functions, where the autarchic unicellular ancestor could perform all of these functions. The developmental pattern was dictated by the specificity of the nuclear matter, by the chromatin.

Unlike in chemistry where a certain molecule under certain environmental conditions will give rise to a certain crystal lattice, even the given unchanged nuclear structure will give rise to beings while similar in shape, in differentiation and in behaviour, show variation on a common theme. Organisms show variability. And it is this variability that was recognised by Darwin as a second potent factor in evolution. While the nuclear structure, seat of heredity characters is, in principle, a fixed entity, the soma, the protoplasm, the vegetative characteristics are variable, and this variability is influenced by the external environment by the "milieu exterieur." However, the above concept would yield only a static structure, unable to account for hereditary changes necessary for evolution.

While we are agreed that such changes must occur, the main question centres on the relative importance of the outer and of the inner world and the interplay between them. Before we consider this question further; it might be of use to consider the concept of symbiosis more in detail. While highly differentiated morphologically, a so called "higher organism" cannot perform more 'chemical feats' than a single algal cell. This morphological differentiation, giving rise to hundreds of different cell types, is an expression of coordinated autosymbiosis. The higher organism is a vital community, a living landscape, a biocoenosis in itself. But only rarely, if ever, it can exist by itself. Apart from its inner coordination, it is equally bound, by many ties, to both the animate and to the inanimate environment. It is only a part of the warp or of the woof of the tissue of life. And, in organic evolution, one organism cannot "move onward" without the necessary readjustment in the whole tissue.

49 See notes above.

50 Refers to Gaillard (1942). Pieter Johannes Gaillard (1907-1992), in 1947, became Professor in Experimental Histology at Leiden University. He finished his book in 1940 at the beginning of WWII. The manuscript was published without his knowledge in Paris in 1942.

51 The parathyroid glands are small endocrine glands in the neck of humans which secrete parathyroid hormones in response to low blood calcium.

52 See Section 7.5.15.

53 Baas Becking's did not have a classical education, so his Greek is not reliable. Perhaps he wanted to refer to the Greek word for 'message': Μήνυμα.

7.4.3 Gamosymbiosis

1) Isogamones (*Polypodiophyta*).

2) Mobile heterogamones (brown and green algae).

3) Sperm and egg (animals, insects, *Nereis*, ferns).

4) Pollen tube and Ambyocea (higher plants).

5) Conjugation in *Conjugales* (*Spirogyra*).

6) Conjugation in *Phycomycetes.*

7) Diplo-haploid [= diploid] mycelium in *Eumycetes.*

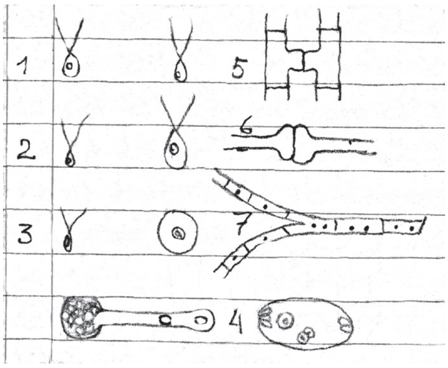


Figure 7.7 Various types of gamosymbiosis.

The scheme in Figure 7.7 gives a few types of gamosymbiosis, which end, in any case, with the formation of a zygote. In case 4, two coalescence products of nuclei are formed the zygote + the endosperm molecule. The latter being triploid. In *Zygomycetes* the + and – myceline grow towards one another attracted by substances secreted by the partner. It is probable that also the pollen tubes are led by a chemical stimulus. The school of M. Hartmann in Berlin, has made a profound study of sexual behaviour in lower organisms, believes in the chemical basis of mutual attraction of gamones.

The chemotaxis of the moss and of the *Pteridophytes* sperm was first discovered by Pfeffer (1884) and Stahl (1884).[54] Here again, different chemical substances (sugars in the case of mosses), malic acid in *Equisetum*, citrine acid in ferns, were the substances secreted by the cells near the ovarium in order to attract the sperms. Apart from the chemical substances which play a part in the secondary sexual characteristic of organisms (obvious) we must assume, in higher animals, the presence of chemotactical substances secreted by the female.

Moewus, Wendt and Kuhn (1938), have found that, in *Chlamodomonas eugametos*, not only sexual behaviour but also mobility was brought about by traces of substances generated by the algae, derivates of crocine, a carotenoid, the cis-and trans-crocetine corresponding to "attraction" substances for male and female respectively. [55] The old experiments of J. Loeb should also be recalled in this connection.[56] Sexual behaviour of cells, gamosymbiosis, is shown to have a chemical basis and differs in no way from other forms of symbiosis.

7.4.4 Phylosymbiosis[57]

There are two important questions before us: primo, is symbiosis possible without evolution and, secundo, the inverse, is evolution possible without symbiosis? The second question was raised by Noel Bernard (1899) later by Bernard and Magrou (1911) and answered in the affirmative.[58] It shall be seen that both questions are closely linked, and that it appears as inconceivable that organisms evoluated by themselves. There should be a "syn-symbiosis": a cow is really 'a grass consuming engine.' Its jaws, its dentation, its stomach, its gut, it is a grass mill. There is a symbiosis grass ⇆ cow, rather one sided, but very real. There is also a

54 Wilhelm Friedrich Philippe Pfeffer (1845-1920), German botanist and plant physiologist. Baas Becking referred to Pfeffer (1884).
Christian Ernst Stahl (1848-1919), German botanist; Baas Becking referred to Stahl (1884).

55 The reference is to Kuhn, Moewus and Wendt (1939). The experiments of Moewus and Kuhn have been extensively reviewed and all attempts to repeat critical features of the work failed. Nowadays the results of his studies are considered as fraud. See Sapp (1990), Deichmann (2001, p. 329-336), Sapp (2003, p.154-166). In the 1953 version of *Geobiology* (p. 601-605), Baas Becking referred to Moewus and Kuhn in the Section *Homoio Symbiosis*, Section *Carotene and Derivatives*. Apparently, he was at that time not informed about the discussion about the validity of Moewus experiments. According to Baas Becking:

> Not only the carotene itself, but many of its derivatives are intimately connected with sexual reproduction, particularly derivatives of the glucoside crocin. Particularly through the work of Kuhn, started before the war, interesting and significant facts have come to light. As Moewus (1950a and b) has complemented his early work by cytological and genetical studies (using, as in the *Neurospora* work, artificially induced mutations), the sexual relations of the green flagellate *Chlamydonomas eugametos* have been shown to be dominated by several specific substances. These substances are formed from precursors by chain reactions, every link in the chain corresponding to one or more genes. *Chlamydomonas* has 10 chromosomes, and 10 linkage groups have been observed. The picture as given by Moewus in 1950 is less homogeneous as it appeared to be in 1938, as flavonol glucosides and their derivatives happen to play an important role. Moewus distinguishes "gamones" *i.e.* ergones, determining the attraction between gametes, further "termones" which differentiate the sexes in hermaphroditic strains. He also finds substances causing flagellar motility and flagellar growth, while also an inhibitor of copulation was found.
> [….] Every step has been checked by genetical evidence obtained by mutants. Moewus also succeeded in isolating several of the substances involved from the *Chlamydomonas* cultures. It is interesting to note that, in his work, Moewus makes no reference of the analogous work with *Neurospora*. Apparently, there has been a parallel development of two, very important, branches of research.

56 Reference to Jacques Loeb who took a decided stand against chemotropism of sperm in animals. See U.B. Kaupp (2012) 100 years of sperm chemotaxis. *J.Gen. Physiol.* 140 (6), p. 583-586.

57 Phylosymbiosis can be defined as microbial community relationships that recapitulate the phylogeny of the hosts. Recent findings indicate that mammalian gut microbiome plasticity in response to dietary shifts over both the life span of an individual host and the evolutionary history of a given host species is constrained by host physiological evolution. Therefore, the gut microbiome cannot be considered separately from host physiology when describing host nutritional strategies and the emergence of host dietary niches.
See Amato *et al.* (2019) and Brooks *et al.* (2016).

58 Noël Pierre Joseph Léon Bernard (1874-1911), French botanist, discoverer of the symbiotic germination of orchid seeds where a soil fungus provides water, mineral nutrients and carbon to the seedling, and compensated for the absence of reserves. Baas Becking referred to Bernard's 1899 article *Sur la Germination du Neottia Nidus-avis*. See Selosse, Minasiewics and Boullard (2017).
Joseph Magrou (1883-1951), cousin of Noël Bernard and his co-author of *Sur les Mycorrhizes des Pommes de Terre Sauvages* (Bernard and Magrou, 1911). After Bernard's early death in 1911 by tuberculose, his ideas were taken up by his former teacher J. Costantin and J. Magrou.
See also Selosse, Boullard and Richardson (2011), Yam and Arditti (2009).
In the 1953 manuscript of *Geobiology* Baas Becking quoted Bernard (p. 590) when he discussed the complexity of symbiosis: […] l'état dit de symbiose est en quelque sorte un état de maladie grave et prolongée […]. In Section *Synevolution* (p. 679-680) he referred to Bernard and Magrou:

> Bernard has discovered an important relation between the formation of tubers, or swollen rhizomes, in higher plants on the one hand, and mycorrhizal fungi on the other. Here a fundamental change should occur, according to Bernard, in the organism infected by the fungus. While the formation or tubers in several orchids did not take place without the fungus, in the potato the tuber formation, by centuries of culture, may take place independent of any previous infection. Here something 'new' has been created. Apart from the Lamarckistic implications of the theory, there is much to be said for the idea, that part of the morphogeny of the higher plant may be "gall formation" by symbiotes.
> The difficulty remains to apply this thought to evolutionary theory. Any symbiosis might imply a "loss" in one or two of the partners. It remains to be seen whether the terrestrial orchids would be able to live without the fungus. If this were the case, the symbiosis would have added something new, the tuberisation. If, however, the plant should appear deficient without its symbiote, if the relation were obligatory, then the combination would be a stable one, acting upon an evolutionary unit. Despite the great mass of fact brought forward to support the theory, however, the direct application to evolutionary theory seems difficult, if not impossible.

symbiosis (as a sort of afterthought) bacteria ⇆ cow, cellulose bacteria, without which the cow would not digest the grass. She maybe, needs the bacteria also to supply her with ergones, or complete protein, or both. In the triangle cow ⇆ grass ⇆ bacteria there is only one autotroph: the grass. There would be no cow without grass. The cow presupposes grass. The tapeworm presupposes a root, the orchid presupposes a digger wasp, the ladybird comes after the aphid, the koala after the *Eucalypt*.

Evolution therefore, has to be syn-evolution. And while the thought of this type of evolution first matured in the brain of a (hereditarily Lamarckistic) Frenchman, we claim that *Lamarckism has never had its proper experimental chance*. It is one thing, like Weismann did to cut off mice's tails and try to raise tailless offspring, *or* to paint salamanders with India ink, like Kammerer, *or* to consider the multitude of ergones, keeping in mind that we already know of naturally occurring substances, like colchicine, that may change the genome of the offspring. It cannot be stipulated emphatically enough that evolution is an anabasis, not of a single specimen, but of a closed mass of various organisms. And that it well may be that changes in the genome, which lie at the base of evolution, are brought about by ergone action. That the excitant, as is known living in symbiosis with the variant, had to look for other fields of endeavour. This is not a neo-Lamarckian that looks to the inanimate environment as an evolutionary agent, but it is a Lamarckian that claims that the *Evolution of organisms, is caused by organisms* apart from the fact that we need creation. The agent of which, according to Spinoza is as active now as ever before, with which beautiful thought the author heartily concurs.[59]

7.4.5 Embryosymbiosis

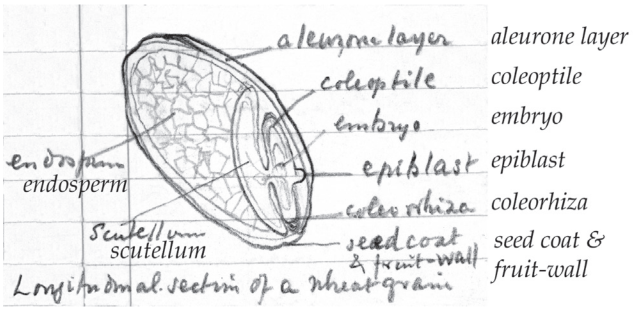


Figure 7.8 Longitudinal section of a wheat grain.

In Figure 7.8 the scutellum is covered by a glandular epithelium known in germination to secrete amylase[60] However, it may secrete a great number of things important for the young embryo that has for a considerable period to be fed from the endosperm.

7.4.5.a Diploid dependent upon haploid

The sporogon is entirely parasitic upon the gamotophyte in liverworts (Campbell, 1905),[61] and in mosses Although the sporogon is arranged with a conductive tissue and with stomates it sucks, by means of a foot, all of its nutrition from the gametophyte. Its CO_2 assimilation, however, is unimpaired. In the lycopod the prothallus may be subterraneous and saprophytic. Here the diploid plant is actually and completely parasitic for years, before it reaches the light (Büchner, 1897a and b). In the forms the case is, in the beginning, somewhat like the mosses. Even in a highly developed plant, as the pine, the young embryo is fed by the primary endosperm, which is nothing but a prothallus, part of the gamotophyte.

7.4.5.b Haploid dependent upon diploid

In the flowering, so called higher plant, before fertilisation we get the reduction divisions of the spore mother cells and the formation of pollen and of the embryo sac. The remnants of the haploid prothallium, which is entirely dependent upon the surrounding tissue of the (diploid) sporophyte. This pertains already in the heterospore Lycopodiaceae (*Selagonella*) and persist throughout *Cycads* and *Gymnospenia* although in these forms the gametophyte is still highly developed. We do not know what type of exchange there exist between haploid and host.

7.4.5.c Diploid upon diploid and upon triploid

(Seeds in plants, usual embryology). In higher plants the young embryo is either surrounded by the diploid cotyledons, like in the legumes, or one find an endospore, which consists of triploid cells. This is, in a way, an organism itself. We find here reserve food, oil, or starch or proteinaceous. On germination this reserve food is mobilised. An egg (bird) is, in a way also a diploid embryo capable of living apart. There is a very complicated parasite relation between embryo and mother, in which exchange of ergones is really the crux of the whole problem of embryology.

7.4.6 Politeia

(*Ezekiel* 27 Faraoh).[62]

Politeia is more than a biocoenosis, it is a number of organisms in such a close community of intent [intentional community] that the obvious analogy with the human state suggests the name given above. Of course, a politeia occurs only where social animals are domiciliated for an appreciable time. There is a great difference between a colony and a politeia. In a colony (*e.g.*, reef coral) community of intent (cilias, movement to move the water) unite, but the components are not actively engaged in promoting it. Ants, bees and wasps and termites are the communities we are thinking about in the first place. There is no doubt that among the ants the civitas is most highly developed. Amongst the higher animals we know nothing of the kind. Schools, flocks, coveys, packs, herds are all concepts which convey a quite different meaning. Only in *Homo sapiens* there reappears politeia, not as a natural thing, but as an afterthought, perhaps as a necessity. The prospective potency of the components is, in human society

59 This section is a remarkable plea for Baas Becking's ideas about 'synsymbiosis'and 'synevolution.' See also Section 5 on, *Adaptation* and Section 7, *Symbiosis and Antagonism*.

60 'Scutellum' is part of the structure of a barley and rice seed – the modified seed leaf. The scutellum is believed to contain an as yet unidentified protein transporter that facilitates starch movement from the endosperm to the embryo.

61 Baas Becking referred to Campbell (1905). Douglas Houghton Campbell (1859-1953) American botanist, specialist in liverworts. In 1921, Baas Becking published his Stanford PhD dissertation (Professor Dr. D.H. Campbell PhD advisor), *The Origin of the Vascular Structure in the Genus Botrychium* (Baas Becking, 1921b). A descriptive study in plant anatomy in which the embryological development of several species of *Botrychium* (a fern also known as moonwort) is described.

62 Possibly reference to *Ezekiel* 32:2. Son of man, take up a lamentation for Pharaoh king of Egypt, and say unto him, Thou art like a young lion of the nations, and thou *art* as a whale in the seas: and thou camest forth with thy rivers, and troubledst the waters with thy feet, and fouledst their rivers.

at least, unimpaired (of *Begonia* leaf, Hartsema, 1926).[63] In animal politeia the smith would have hammer instead of hands, and the carpenter perhaps a saw or chisel. Our plasticity may be, however, not externally fixed.

7.4.7 Summary and conclusions

In a way, the syn-evolution proposed by Bernard (1899) and by Bernard and Magrou (1911), is nothing novel. It is apparent that the organisms in themselves form a 'web of life' just as much as they, naturally form such a tissue. We are driven, *nolens volens*, to a novel form of Lamarckism, an evolution induced by ergones. We see, in the ascending series, an increasing amount of chemical dependence, of 'chemical helplessness', going hand in hand with an increase in morphological and functional differentiation. However, in the plant kingdom, there is another type of evolution. Here the organism, while developing morphologically, has kept its prospective potencies.

Text box 7.3 – Baas Becking notes made prior to writing the manuscript

"Zooxanthellae" (*chrysudella*) [?],[64] in *Foraminafera* and *Radiolaria,*

"Chlorella",[65] in *Paramoecium aurelia*,[66] *Stentor amethystine*.[67]

Hypermastigina, termites and woodroach, *Cryptocercus*,

Cleveland demonstrated digestion of cellulose, see Fig. 129-131.[68]

Trichonympha, Leptospironympha from stomach ruminants 1937.

Kudo, Fig 167, 19.[69]

Charles Nicolle, *Naissance, Vie et Mort des Maladies Infectieuses*.[70]

Noel Bernard, 1909.

Parasitium, commersalism.

Cyclic *Ardisia, Lolium, Calluna*. MIMICRY.

Reinfectuous legumes, *Hippophae, Mycetomes, Gunnera, Lichens, Cycas, Podocarpus, Zooxanthellae, Termites, Azolla, Lemna, Livenruts, Orchids, Lycopods, Eusporangiates*, artificial symbiosis, catotrophic mycorrhi, strawberry Antlers.

7.5 Heterosymbiosis, Simultaneous

7.5.1 Introduction

The two-toed sloth *Bradypus* has hairs with a furrow, in which a green filamentous alga lives (see Weber-van Bosse, 1887).[71] Mammals should not be green, like lizards or caterpillars, for they are able to metabolise the chlorophyll entirely. Therefore, when my friend Walter Spies told me that he had shot a green bat on the island Nusa Perida, south of Bali,[72] I expected a symbiotic alga. As a specimen of the bat was present at the Buitenzorg collection (*Dobsonia viridis*), v. Bemmel,[73] assistant curator examined the hairs and actually found a bluegreen alga *within* its hollows, bifurcated hair. The observation was extended to *Dobsonia* hair obtained from the Amsterdam Zoological Museum, through the kindness of its curator L.F. de Beaufort.[74] Here also the alga was found. This is a case of an epiphytic alga, an arbitrary relation between two organisms. Now the relations between organisms are manifold (see Section 5.2.3). In the following pages we shall deal chiefly with mutualistic symbiosis. A full description of the cases would require an extraordinary amount of space. Mutual influence is so pronounced that we have used the term 'web of life' to it (see Section 1.4, Fig. 1.1, Section 4.9.5 and Tables 7.2a and 7.2b).

63 Anna Martha Hartsema (1896-1975) defended her doctor's thesis May 12, 1924 in Utrecht: *Over het Ontstaan van Sekundaire Meristemen op de Bladeren van Begonia Rex* (Hartsema, 1926; PhD advisor F.A.F.C. Went). She was well known to Baas Becking as a colleague in the Utrecht Botanical Laboratory. She became a scientific researcher in the Agricultural University Wageningen.
In the manuscript of the 1953 *Geobiology* Baas Becking referred to Hartsema (p. 685):

> The regeneration of a *Begonia* plant from a single epidermal cell is by no means proved (Hartsema, 1926). In the foliar buds of *Bryophyllum*, in the gemmae of *Marchantia*, in the fronds of viviparous ferns. It is a group of cells rather than a single cell which gives rise to a new individual.

64 *Zooxanthellae* is a colloquial term for single celled dinoflagellates that are able to live in symbiosis with diverse marine invertebrates including corals, jellyfish and nudibranchs.

65 *Chlorella* is a genus of single celled green algae belonging to the division of Chlorophyta.

66 *Paramecium aurelia*, unicellular organism.

67 Amethyst deceiver, *Laccaria amethystina*, a small brightly coloured mushroom that grows in deciduous as well as coniferous forests.

68 A number of genera in the group *Hypermastigina* (flagellates) inhabit the intestines of termites and cockroaches. The Hypermastigina are able to digest cellulose, an ability which generally does not occur among animals.

69 *Cryptocercus punctulatus* Scudden, a cockroach eating wood. Cleveland *et al.* (1934) found that all *Crytocercus* had the flagellate *Barbanympha* in their stomachs and the enzymes cellulase and cellobiase. Further *Cryptocercus* have two protozoa symbionts *Trichonympha* and *Leptospironympha* in their intestines.
See also Kudo (1926).

70 Baas Becking inserted this reference to Charles Jules Henry Nicolle (1886-1936), French bacteriologist, winner Nobel Prize in Medicine (1928) for his identification of lice as the transmitter of epidemic typhus. See Section 5.10.13 *Epidemiology*.

71 Reference to Weber-van Bosse (1887). She described *Trichophilus welckeri* Weber-van-Bosse. This is a subaerial species occurring in the fur of brown-throated, three-toed sloth (*Bradypus variegatus*; Bradypodidae) and the pale-throated, three -toed sloth (*Bradypus tridactylus*) which occur from Nicaragua to Brazil. Their long, coarse, thick hair is brownish-grey in colour and takes on a greenish tinge in the rainier season when *Trichophilus* forms on its back.

72 Walter Spies (1895-1942), Russian-born German primitivist painter, composer, musicologist and curator. In 1923, he moved to Java, Indonesia. He lived in Yogyakarta and then in Ubud, Bali. In 1938, he was arrested as part of a crackdown on homosexuals, released in September 1939. As a German national in the Dutch East Indies, he was taken prisoner when WO II broke out. He was one of the victims on the *Van Imhoff* that transported the German prisoners to Ceylon and that was torpedoed by the Japanese. The German prisoners were not rescued, only the Dutch passengers and crew.
See Ross (2000).

73 Adriaan Cornelis Valentin van Bemmel (1908-1990), zoologist, in 1937 assistant curator Zoological Museum Buitenzorg, returned from Indonesia in 1951. Later director of the Rotterdam Blijgaarde Zoo and the Rotterdam Nature History Museum.

74 Lieven Ferdinand de Beaufort (1879-1968), Dutch biologist, participated in 1903 in the North New Guinea Expedition. In the 1920s director of the Artis Zoological Museum Amsterdam. Professor in Zoogeography University of Amsterdam.

7.5.2 Cyclic symbiosis

Ardisia Miehe (1911 and 1917), de Jongh (1938), Bok.[75] [See also Section 6.4.2.b]

[Baas Becking inserted Fig. 7.9.]

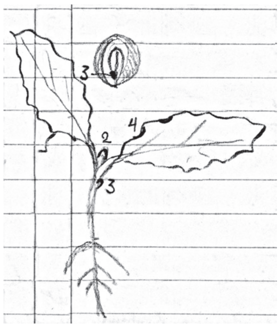


Figure 7.9 Sketch of *Ardisia*.

7.5.3 Lolium

Mej J. van Roon.[76]

7.5.4 Calluna

Rayner.[77]

7.5.5 Non cyclic symbiosis Legume

Hellriegel and Willfahrt (1888), Beijerinck (1888), Fred, Allen, Löhnis (1941), Virtanen.[78]

7.5.6 Hippophae, Alnus, Elaeagnus[79]

[Baas Becking inserted Fig. 7.10.]

Roberg (1934 and 1938), v. Oven, Honbold [?].[80]

7.5.7 Gunnera

[Baas Becking inserted Fig. 7.11.]

75 The reference is to the studies of Hugo Miehe about *Ardisia crispa* symbiosis after his sojourn at Buitenzorg and published in 1911, in his *Javanische Studien* and in Miehe (1917). Ph. De Jongh worked at the Leiden Botanical Laboratory and confirmed the symbiosis *Ardisia* and bacteria in 1938. Ph.J. de Jongh (1938). *The Symbiosis of Ardisia Crispa*, PhD Thesis Leiden (Baas Becking PhD advisor).

In the 1953 *Geobiology* manuscript, Baas Becking referred to their studies on p. 623-624 under the heading *Action of Microbiotes on Higher Plants, Foliar Bacterial Symbiosis.*:

> The bacteroids, present in these nodules were interpreted by him as "proteinaceous glands." Hugo Miehe, after a sojourn at Buitenzorg published a detailed account of the *Ardisia* symbiosis in his *Javanische Studien* (Miehe, 1911). The bacteria are present in the growing point of the plant. Infection of the leaf margins occurs in the hydathodes of the young leaves. Constrictions occur at the margins and in the centre of these contrictions we find the bacterial nodules. In the seed Miehe found bacteria between the embryo and the endosperm. With this study Miehe gave the first example of a cyclic symbiosis between a higher plant and a bacterium, as extraneous infection (as in the *Leguminosae*) does not take place. In a later study Miehe describes the bacterial component and, in a third study, the bacteria-free *Ardisia*. The latter is a veritable 'cripple', it remains dwarfed, and never flowers. At the Leyden Laboratory, Ph. de Jongh could confirm the results of Miehe (1917). He, moreover, succeeded in following the course of the cyclic symbiosis from seed to seed. The bacterial film, which covers the vegetation points, is enclosed between the carpels. The bacteria finally surround the ovules and are entrapped by the growing integuments at the micropylar region between the two parts of the inner integument. After the (apogamous) development of the embryo, the bacteria adhere to its radical pole, where they remain in a resting, but reversible, state. (this in contrast with the bacteroids in the leaf nodules, which are irreversibly changed). At germination the bacteria. are pushed over the cotyledons, where they infect the axillary bud, while a bacterial mass also infects the terminal bud. Seeds could be made bacteria-free by heating them to 40 °C. The bacteria-free plant, the cripple, has a juvenile appearance. Longitudinal growth stops over the entire plant, the root excepted. The meristematic cells are large, the leaf primordia remain undifferentiated, while the axillary cotyledonary buds proceed to proliferate for years, forming a wart-like gall. The 'cripple' contains catalase and peroxidase in the terminal bud while the normal plant seems to lack peroxidase. Application of heteroauxin only caused root formation on stem and petioles, but could not cure the cripple. Cleft grafts of normal on cripple or vice versa showed the root system of the crippled stock to be stimulated by the normal scion. Very young cripples may be artificially infected.
>
> As in the foliar symbiosis of *Rubiaceae* (*Pavetta*, *Psychotria*), fixation of atmospheric nitrogen has been claimed by von Faber (1912-1914), it seems remarkable that the *Ardisia* system apparently expresses a different relation. de Jongh thinks that a growth promoting substance (not identical with heterauxin) may be produced by the bacteria. As the presence of a high peroxidase seems typical for other 'dwarfs', where the dwarfing is caused by mutation of a single gene, it may be that the bacterial film acts as an "oxygen absorber", reducing the oxygen pressure at the vegetation point. It seems highly significant that R. Bok, at our laboratory, succeeded in inducing growth *Ardisia*-cripples in oxygen-nitrogen mixtures with a lowered oxygen tension (1941). However, the real nature of the consortium remains unexplained. The relation, while cyclic, remains intercellular.

R. Bok was research assistant 'without objection from the Governments Treasury' ['buiten bezwaar van 's Rijks Schatkist'] at the Leiden Botanical Laboratory from March till September 1941. In 1946, she worked on soil optimalisation for *Lathyrus* culture at the TNO laboratory in Delft. Her 1941 experiments were communicated to the Dutch Academy of Sciences by Baas Becking (Bok, 1941):

> These preliminary results seem to give a strong indication that the hypothesis, stated in the work of P.H. de Jongh, according to which the bacterial film on the stem vegetation point of *Ardisia crispa* lowers the oxygen tension in the stem meristem, contains elements of truth.

76 Darnel, ryegrass (*Lolium temulentum*, L.), has been known since Roman times for the poisonous properties of its grain. It was not, however, until 1898 that the presence of an often considerable layer of hyphæ was discovered just exterior to the aleurone layer of the grain; to the action of this fungus layer the poisonous properties are presumably due. In his PhD thesis Quispel (1943, 1946, p. 419) referred to the research of "fungus symbiosis of *Lolium temulentum* by J. M. van Roon and Mr. J. v. d. Drift" in the Leiden Botanical Laboratory".

In 1941, van Roon was an assistant employee at the Leiden Zoological Laboratory. Joop van der Drift worked after WWII at the Instituut voor Toegepast Biologisch Onderzoek in de Natuur (ITBON). He defended his PhD thesis in 1950 in Leiden. He initiated an integrated study on various factors influencing soil life in a small forest of Hackfort in The Netherlands.

77 Reference to Mabel Mary Cheveley Rayner (*c.* 1890-1948), english mycologist, in 1913 Lecturer in Botany, University College, Reading. Rayner thoroughly reviewed academic research into mycorrhizal research.

78 Reference to Hellriegel and Wilfarth (1888), Beijerinck (1888), Beijerinck (1918).

'Fred' refers to Edwin Broun Fred (1887-1981), American bacteriologist, President University of Wisconsin-Madison. In *Geobiologie* (1934, p. 85 English edition, 2016), Baas Becking referred to Domogalla and Fred (1926) on solubility of ammonia and nitrate in freshwater.

"Allen" refers to the Ethel K. Allen (1906-2006) and Oscar Nelson Allen (1905-1976), bacteriologists at University of Wisconsin, who published the results of their 45 years of research in 1981: *The Leguminosae, a Source Book of Characteristics, Uses, and Nodulation* (Allen and Allen, 1981).

"Löhnis" refers to Dr. Marie Petronella Löhnis, a plant pathologist who worked in the 1930s and 1940s on boron deficiency at the Wageningen Landbouwhogeschool (Löhnis, 1941).

Artturi Ilmari Virtanen (1895-1973), Finnish chemist recipient 1945 Nobel Prize in Chemistry.Virtanen worked at the Laboratory of the Foundation for Chemical Research in Helsingfors (Finland) on root nodules of *Leguminosa*.

79 The species mentioned by Baas Becking have nitrogen fixing root nodules. See Hawker and Fraymouth (1950).

80 'Oven' probably refers to A. van Oven, a student of Baas Becking in Leiden. Miss Oven participated in the field research of the Leiden Biologist Club in Wijster, autumn 1932, where she demonstrated the presence of bacteria in the air cells of *Sphagnum cymbifolium* (Baas Becking and Nicolai, 1934). In *Geobiology* (1953, p. 581) Baas Becking mentioned:

> Miss van Oven studying the acid water of a peat bog found active sulphate reduction and anaerobic acid formation by Plectridia [Glucose and cellulose fermenting hammer-shaped or drumstick-shaped bacteria].

Reinke (1873), Hansen, Baas Becking (1947a) and Hulssen (1946).[81]

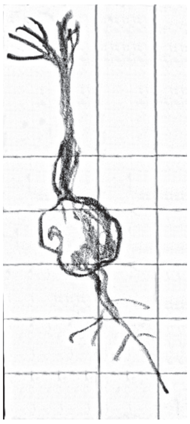


Figure 7.10 Sketch of plant.

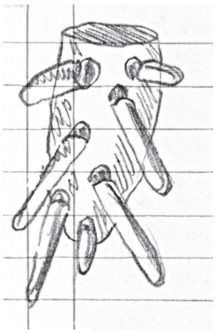


Figure 7.11 Sketch of *Gunnera*.

7.5.8 Cycads

In all of the *Cycadaceae* inspected by me in the Botanic Garden Buitenzorg Java 1939, as with *Cycas*, *Encephalartos*, *Zamia*, *Macrozamia*, *Stangeria*, *Dioon*,[82] the roots, especially those near the surface, show nodular excrescences which, on closer examination show dark green under the surface (Fig. 7.12). Bluegreen algae, intracellular are the cause of these nodules and of the colour. Sometimes the colour is non-existent, the cells seem therefore to contain still another organism apart from *Nostoc cycadae*. Bacteria have been repeatedly found within the cells. Experimentation is still lacking, but it may be that, like in the case of *Gunnera*, root formation is stimulated by the bluegreens (+bacteria?) according to Galestin (1933),[83] *Nostoc cycadae* to capable of assimilation of atmospheric nitrogen. Obviously, when this were the case, it may be that, apart from ergones, the *Cycas* is supplied with amino acids, which for some reason it needs.

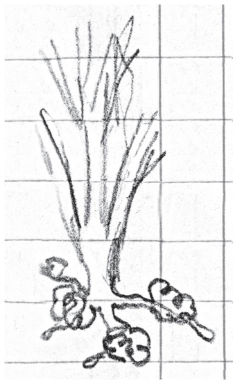


Figure 7.12 Sketch of roots of *Cycas*.

7.5.9 Lichens

[Baas Becking inserted Fig. 7.13.]

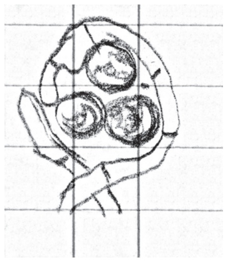


Figure 7.13 Sketch of lichen.

De Bary (1864 and 1879), Schneider (1898), Jacq, Quispel (1943 and 1946).[84]

7.5.10 Endothophic mycorrhiza

Orchids.

Bernard (1909), Rumpff (1741-1750).[85]

7.5.11 Lycopods, Eusporangiates

Treub, Jacq., Campbell (1905), Bruchmann (1906).[86]

81 'Hansen' is possibly F.H. Hansen, of the Forest Research Institute, Buitenzorg, Java. In the 1953 manuscript of *Geobiology* Baas Becking referred on p. 621 to:

> The curious algal symbiotes in *Cycadeae* and in the 'giant herb' *Gunnera* have attracted much attention since Reinke (1873) described the "algal zone" in the root or *Cycas*. […] In *Gunnera* (studied by Reinke and later by Miehe) the algal galls (formed by internal infection of the rhizome through the mucilaginous glands) were found to occur always above a root primordium. Just before the war, van Hulssen, at Buitenzorg showed that heterauxin was present in the algal colonies (*Gunnera macrophylla*) (see Baas Becking, 1947a). The experiments were repeated by Dykshoorn in Leyden with *Gunnera manicata*, and our earlier results confirmed. It also appeared that the plant contributed minimum substances which influenced favourably with growth of the alga. […] It seems that the *Gunnera* rhizome is not capable of forming roots without the algal symbiote. This does not exclude the possibility of nitrogen fixation by the alga, but from the relation between the galls and the root formation it appears to be obvious that the chief role of the *Nostoc* may be its contribution of root-forming substances.

82 Baas Becking inspected genera from the order *Cycadales*. The *Cycadaceae* are a family of the suborder *Cycadineae* with one genus *Cycas* with about 115 species. From the suborder *Zamlineae* he mentions the genera *Stangeria*, *Dioon*, *Encephalartos*, *Macrozamia* and *Zamia*.

83 Galestin repeated the experiments of Beijerinck with isolated root nodules of several *Legumiosae*.

84 References to De Bary (1864), De Bary (1879) and Schneider (1898). 'Jacq' is Nikolaus Joseph von Jacquin (1727-1817).

85 See for Noël Bernard and mycorrhiza of orchids Sapp (1994, p. 13-14) and Selosse, Boullard and Richardson (2011).
The reference to Rumphius is to Georgius Everhardus Rumphius (1627-1702) and his *Amboinsche Kruidboek* (1741-1750). According to E. Beekman in *Rumphius' Orchids* (Beekman, 2003, p. xlv-xlvi):

> Rumphius was the first botanist to describe epiphytes and to intuit that these plants were not parasites but that their arboreal hosts were only something of a perch. He was the first to describe orchid seed [….] and seems to have comprehended that orchid seeds are dispersed by the wind. He also clearly understood orchid fruits and was the first to note the presence of pollinia, which have been defined as "more or less coherent masses of pollen."

See also Beekman (2011), G.E. Rumphius, *The Ambonese herbal*, which is a wonderful annotated English translation of Rumphius' botanical work.

86 "Treub" referred to Melchior Treub (1851-1910), from 1880-1909 based in the Dutch East Indies as director of the Bogor Botanical Gardens at Buitenzorg. In the period 1884 till 1890 he published about *Lycopodium Cernuum* in the *Annales du Jardin Botanique de Buitenzorg*.
H. Bruchman published on the prothallium of *Lycopodium*. Baas Becking (1921b) referred to Bruchmann (1906).

7.5.12 Lemna, Liverwort

Azolla.
Straszburger. [87]

7.5.13 Zoosymbiosis, Protozoa

[Baas Becking left this section blank.]

7.5.14 Zooxanthellae

Corals, sea anemones, hydra's, sponges, de Laubenfels (1930), Boschma, Verwey.[88]

In unicellulars, protozoa such as *Paramoecium bursaria*[89] and *Stentor amethystinus*[90] we meet with unicellular green algae, which one named (by their negative characteristics) *Chlorella*. In other protozoa, foraminifera and radiolaria, we meet with yellow symbiotic algae, *Chrysidella*. In higher forms such as hydra's, anemone's, sponges, corals we always speak about *Zooxantellae*, and the colours of the symbiotic algae have may be, as a matter of fact, either green or orange-brown. The latter colour is caused by the phenomenon of climatisation and is a typical deficiency phenomenon.[91] Evidently, in this case, the host has not been able to meet the requirements of the symbiont (NO_3^-, $H_2PO_4^-$). A great many algae, (*Polyblepharids*, *Protococcales*, *Conjugates*) when brought in adverse conditions, will develop their carotenoid pigments in anomalous quantities (see Vreede, 1941?).[92]

7.5.15 Mycetomes[93]

Buchner (1921) in his classical treatise has shown that a great many insects contain certain glandular structures in or near the gut which contain bacteria, yeasts or other fungi.[94] It is surprising that blood drinking insects are often provided with mycetomes, showing that, apparently, they do not derive all of the necessary ergones from the host. Apart from the mycetomes, they apparently have other sources of ergones. The aphids, for instance, reach a sexual period often when the host plant starts flowering. If this is a short day plant, the aphid shows two periods annually (*Aphis forbesi* on strawberry; MacKoritch cited in Shelford, 1929).[95]

7.5.16 Termites

The *Hypermastigniae*, an order of the flagellate protozoa, are symbiotic with termites and with woodroaches such as *Cryptocercus* (Kudo, Fig. 119-131). There are a great many of these protozoa for a large part described by Kofoid and Swezy.[96] The adult termite does not attack wood; it lives on the excrements of the larvae. The larva is able to destroy wood or rather, as Cleveland has demonstrated,[97] the fauna of the gut, whether solely protozoa in character or in combination with bacteria, is able to digest cellulose. Here we meet with a close analogue with what we find in ruminants.

7.5.17 Herbivorous mammals

The Australian marsupial, our well known Koala, lives on the leaves of very special *Eucalypts*. In a ruminant and compound stomach the leaves undergo an alcoholic fermentation, banning the animal to be more or less continuously sleepy and, unfortunately cross. Here symbiosis should probably include a yeast, although bacteria may also generate alcohol from sugar.[98]

7.5.18 Higher forms of symbiosis

Galls.

7.5.19 Artificial symbiosis

W. Schöpfer was the first, in 1934, to realise an artificial symbiosis between a red yeast *Torula rubra* and a phycomycete *Phycomyces blakesleeanus*. Both organisms are heterotrophic and, moreover, aneurine deficient. *Torula* is able to synthesise the thiazole half; *Phycomyces* the pyridoxine half of the molecule. They are therefore, only together a stable

87 Eduard Adolf Strasburger (1844-1912), Polish-German botanist.

88 Max Walker de Laubenfels (1894-1960), American spongiologist. The reference is to Laubenfels (1930).
Hilbrand Boschma (1893-1976), Professor of Systematic Zoology, University Leiden and director Museum Natural History Leiden (1933-1958). His chief interest was in systematic zoology particularly that of rhizocephalan crustaceans and stony corals. See Vervoort (1977), *Prof. Dr. Hilbrand Boschma 1893-1976*.
Jan Verwey (1899-1981), marine biologist and director Zoological Station Den Helder (1931-1965). From 1922 until 1931, he worked as a fishery biologist in the Dutch East Indies.

89 *Paramecium bursaria*, a ciliate in marine and brackish waters, has a mutualistic endosymbiotic relationship with green algae called *Zoochlorella*. The algae live inside the *Paramecium* cytoplasm.

90 *Stentor amethystinus*, trumpet animalculus, filter feeding heterotrophic ciliate.

91 Baas Becking referred to the phenomenon of coral bleaching which occurs when coral polyps expel algae that live inside their tissues in an endosymbiontic relationship. The cause of bleaching is rising water temperature.

92 Possibly a reference to Wolvekamp and Vreede (1941).

93 Mycetomes are symbiotic microorganisms, which aid in the digestion of vertebrate blood.

94 Reference to Paul Buchner (1886-1978). See also Sapp (1974, pp. 109-11).

95 Baas Becking referred to Shelford (1929, p. 322).

96 Charles Atwood Kofoid, worked on plankton organisms and protozoa, as Professor of Zoology from 1903 until 1936 at Berkeley and after his retirement in 1936 until his death. His most important contributions to the morphology of the protozoa were made during his association with Olive Swezy (1878-?), zoologist and phycologist at Scripps Institute and University California.
See Goldschmidt (1951).

97 Reference to Cleveland (1923), Cleveland *et al.* (1934).

98 The Koala's digestive system is especially adapted to detoxify the poisonous chemicals in the eucalyptus leaves. Koalas have a special fibre digesting organ called a caecum (200 cm). The caecum contains millions of bacteria which break down the fibre into substances which are easier to absorb. Even so, the Koala is still only able to absorb 25 percent of fibre eaten. Water is also absorbed from the gumleaves, so that Koalas rarely need to drink, although they can do so if necessary, such as in times of drought when the water content of the leaves is reduced.

combination. This finding opened our eyes to the real significance of symbiosis and not much later Kögl and Fries (1937), see also Funke (1943).[99]

7.5.20 Mimicry

Walking leaf, branch, *Mantis* (there is a crustacea like this).

Bug *Reduvius*.

For merfly like bumblebee.[100]

Mottled background fishes, salamander.

Velvet ants.[101]

Orchids and wasps.

Moths.

Birds eggs.

Winter pelts in mammals.

Geometer caterpillars.

7.5.21 Summary and conclusions

[Baas Becking inserted Fig. 7.14.]

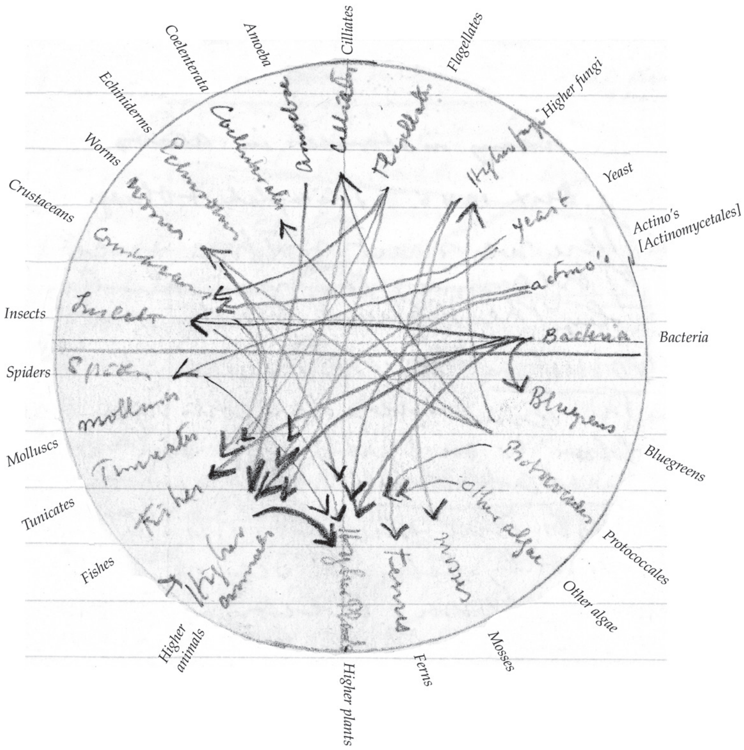


Figure 7.14 Schematic representation of interactions between microorganisms and higher organisms.

> ***Text box 7.4 – Baas Becking notes made prior to writing the manuscript***
>
> H. [= G.W.] Harmsen diss. many instances in aerobic cell describe metabiosis.[102] See Derx (1943). Silicaplate + bluegreens, later *Azotobacter*, see Dooren de Jong, Funke.[103]

7.6 Hetero-Symbiosis, Succedaneous (Metabiosis)

Here we meet with a succession of organisms, the medium begins presequent by the sequent for the subsequent.

7.6.1 Introduction

As there seems to be a certain contradiction in the term succedaneous symbiosis. The author shall follow a suggestion of H.G. Derx and use the term *metabiosis*.[104] The question

99 In his 1953 version of *Geobiology* (p. 613), Baas Becking described under the heading MUTUALISM:
Rhodotorula rubra and *Mucor ramannianus*, *Polyporus versicolor* and *Nematospora gossypii* are classical examples of "laboratory symbioses" described, respectively by Schöpfer (1935) and Kögl and Fries (1937). These organisms, each deficient in a certain minimum component, showed good growth when brought together. In the case of Schöpfer's symbiosis each component could perform a part synthesis of the thiamin necessary for growth, respectively the thiazole and the pyrimidine parts, while *Polyporus* requires thiamin, provided by *Nematospora* while, in its turn, it produces the biotin which cannot be synthesised by the *Nematospora*. So, it seems evident that, in heterosymbiosis as well as in homoiosymbiosis, we deal with "humoral phenomena" and, as in pathology and in physiology, definite solutes are involved.
In the same manuscript (p. 614 and 615) under the heading *Excretions of Higher Plants, Mainly Foliar, and their Influence* Baas Becking referred to Funke (1943):
G.L. Funke, in 1943, described an interesting effect of the excretions of *Artemisia absinthum* (which he called "absinthein") on other plants. *Salvia*, *Nepeta* and a number of others were suppressed in their growth when planted within five feet of the absinth. When planted within 40-50 cm from the absinth, they became dwarfed.

100 *Volucella bombylans* occurs in several forms, each of which mimics a species of bumblebee. The two main varieties are *Volucella bombylans var. bombylans*, showing an orange-red tail, mimicking the red-tailed bumblebee (*Bombus lapidaries*) and *Volucella bombylans var. plumata* with a white tail, mimicking the white-tailed bumblebee (*Bombus lucorum*) and the buff-tailed bumblebee (*Bombus terrestris*).

101 For the colour mimicry of the 65 species of the *Dasymutilla* velvet ants, see Funke (1943).

102 See for G.W. Harmsen Sections 3.9. and 4.8.

103 Dr. Louis Edmond den Dooren de Jong (1897-1972), bacteriologist, pupil of Beijerinck. Baas Becking referred to Den Dooren de Jong (1938).

104 Henri Derx (1947) published about symbiosis and mentioned Baas Becking's unpublished views for which he referred to the PhD thesis of Anton Quispel (1943/1946).

remains whether there exists true metabiosis. Of course, all actors are present, only behind scenes or, biologically speaking, in latent form. According to some, and the number of examples is countless, they are always present also in the vegetative stage, but their numbers are small (examples may be given from lactic acid bacteria, *etc*.). There are instances, however, of true metabiosis, where the milieu has to be prepared and *for* organism B *by* organism A.

7.6.2 Saprophytism

Intestinal symbionts are known to synthesise several ergones. The rat, for example, does not need vitamin C, it prepares it in its gut, or rather its microfauna prepares the ascorbic acid. (Giroud, *L'acide Ascorbique*).[105] Now it is remarkable that many microbes live on manure. It is said that the former Professor of Botany at Amsterdam, C.A.J.A. Oudemans, already in the 'sixties' gave a course in microbiology.[106] To this end horse manure was put under a bell jar, and the developing flora observed daily! (See also Lindner, 1888, Gärunggewerben).[107] First *Mucor* appears, then *Thamnidium elegans*, followed by *Pilobolus*, *Sordaria firmicola*, while the series ends with *Coprinus*. Now this may very well be a true metabiosis, but on a very rich nutrient medium, in which many ergones are already present! Cow manure seems to be particularly rich in ergones, as the work of H.G. Derx (in litteris) shows. Thaxter has shown that *Myxobacteria* are typical for rat and rabbit dung, while *Humaria*, *Peziza* and other *Discomycetes* are common on cow and deer excrements.[108] Saprophytes on *humus*, also a complicated, ergone-rich, mixture, is, of course better known. It is possible that a weird practice of the anthroposophist's, called "biological-dynamical" method of manuring, in which a compost is prepared with many ingredients, really is efficient because of the number of ergones it introduces into a metabiosis. The formation of the so called "Edelkompost" should therefore remain a *biological* process and never be degraded to a chemical manipulation, as several modern patents claim to make "humus" out of refuse at high temperatures with NH_3 etc.

7.6.3 Pütters hypothesis[109]

Already in 1908 Pütter claimed that there should be a certain amount of soluble organic matter in natural water which might serve as food. The Wisconsin survey has investigated this matter and found indeed in Wisconsin lakes organic material in hue solutions as the following Table 7.4 shows.[110] However we know now, especially after the work of Moewus and Wendt that organic substances functioning as ergones are active in very low concentrations (---γ/L for excretion) so that Pütter's hypothesis obtains renewed significance, not so much as a source of *caloric* food, but as a source of nutrilites.[111] This necro-symbiosis when hetero-symbiotic, may be succedaneous.

Table 7.4 Organic matter in Lake Mendota (Wisconsin). After Birge and Juday (1911).

0.393 pp 106 org N
5.80 pp 106 org C
In plankton
0.140 pp 106 org N
0.990 pp 106 org C
14 mg/L organic matter; 10% plankton

7.6.4 Succedaneous cultures

The literature on the brine bacteria claims that there are freshwater forms living at low temperatures. As I found empty sheaths of these bacteria at solar salt water near Bombay and also on the island of Madura, this claim seemed erroneous. As I was unable to culture the *Gallionella* directly (except in freshwater at low temperatures), I used the methods of succedaneous culture, which is an example of metabiosis. Use was made of filter paper pulp and in organic medium, infection was with diluted mould, the whole jar kept anaerobical. At first there appeared cellulose bacteria, anaerobic forms, which at first made some gas but soon ceased in doing so when the next group, the sulphate reduction bacteria appeared. Due to the presence of ferro-iron, ferro-sulphide (FeS) or troilite was formed until the contents of the entire jar became pit black. Now air was admitted and then within a few days the aerobic sulphur bacteria appeared, which changed the S, formed by the non-biological oxidation of FeS, to sulphate. When moreover the bottle was placed in the light, development of purple bacteria could be seen within 10 days at low temperature. Now the conditions for development of iron bacteria were fulfilled! There was Fe^{2+} and oxygen, at the surface of the synthetic mould they appeared, at 35 °C, in strong brine!

Now this method suggests a great number of possibilities and a number of microbes that have been refractory to cultivation might develop in the media (Harmsen).[112]

105 Probably a reference to Giroud (1938).
Humans and other primates have lost the ability to synthesise ascorbic acid (ASC; vitamin C). Unlike primates, mice and rats are able to synthesise ASC. See Gabbay *et al.* (2010).

106 C.A.J.A. Oudemans (1825-1906), Professor of Medicine, Botany and Pharmacology University Amsterdam 1859-1896.

107 Reference to Lindner (1888), *Die Sarcina-organismen der Gärunggewerbe*. 'Gärunggewerbe' are fermentation techniques.

108 See for Thaxter. Section 7.2.1.

109 In the 1934 *Geobiologie* Baas Becking discussed Pütter hypothesis (p. 85 and 86, English edition). His reference was to Pütter (1911). According to H.W. Harvey (1928, p. 29):

> The part played by the traces of filter passing organic matter, occurring in seawater, upon the physiological processes of marine animals in nature, is by no means clear. Pütter (1909) has advanced a theory that they absorb much of their nutriment in the form of dissolved organic matter, but the theory has not been generally accepted on the ground that much subsequent experimental evidence has failed to show any such absorption, and that there is plant life sufficient to support them. The capability of higher marine organisms to obtain nutriment by absorbing dissolved organic matter themselves is not definitely proved or disproved. That marine bacteria and possibly many protozoa utilise these dissolved substances and keep their concentration low in the open sea is probable, if not certain.

Harvey (1928) also referred to Pütter (1909). According to Korringa (1949), the controversy 'once argued ardently' by Pütter, whether or not dissolved organic matter can be used as food by marine organisms, is generally thought to be settled with Krogh's conclusion (1931): 'There is no convincing evidence that any animal takes up dissolved organic substance from natural water in any significant amount.'
See Krogh (1931), *Dissolved Substances as Food of Aquatic Organisms*.

110 Reference to Birge and Juday (1911). Also quoted in Baas Becking *Geobiologie* (1934). The reference is to Edward Asahel Birge (1851-1950) and Chancey Juday (1871-1944), pioneers of North American limnology.

111 See Kuhn, Moewus and Wendt (1939) and Moewus (1950a and b) and Section 7.4.3. The reference is to the sex determining substances found in *Chlamydomonas eugametis*. They found that besides 'Gamonen' also another sex determining substance, 'Termone' was excreted by the gameten. The male determining was oxaldehyde of Safran, the female determining was isorhamnetin. Both substances were still active in extraordinary dilution of about one molecule *per* cell.
Nowadays the results of Moewus studies are considered as fraud.

112 See for G.W. Harmsen above.

Apparently the succedaneous (or cyclic) culture originates subsequently a number of ergones which number increases as the culture proceeds. It would be a beautiful field of research to study such succedaneous phenomena. Cellulose fermentation is a promising starting point, as in nature cellulose materials often function as "initiators" of cycles.

7.6.5 "Bodemmüdigkeit"

(Söhngen and pupils).[113]

(Bacteria followed by phage). After the discovery by Twort and Hérelle of the bacteriophage,[114] agricultural bacteriologists have demonstrated that lytic agents occur in soil bacteria as well. *Radiobacter beyerinckii*, nitrifies and other bacteria show the typical "parasite" in culture. It has been assumed that protracted sterility of soils, such as are met in the Residency of Indramaju in Java, might be caused by the development of certain soil bacteria. The concept is somewhat too much simplified as soil fertility implies an enormous biotic cycle in which both metabiotic and symbiotic phenomena should occur.

7.6.6 Spoilage of water and biological purification

Biological purification, whether in rivers or in septic tanks is a typical metabiosis. Spoilage, of course, is a more or less anthropocentric term, but it may mean an accumulation of organic substances in water, changing thereby its character in such way that it becomes unfit as potable water, industrial or fish water. The accumulation of organic matter, however, incites various swaps of microbes to great activity and *mineralisation etc*.

The classic case is the purification of the Illinois River below Chicago (Kofoid, 1903),[115] or the septic tank and filter system. Here first enormous numbers of bacteria develop, which, in their turn, are consummated by protozoa. If the water is sufficiently aerated, the end products of mineralisation (protein, fats, sugar) are nitrates, sulphate and carbon dioxide. Even so called antiseptics, like phenol, are finally broken down. There are fungi however, certain cases, where mineralisation is incomplete (sulphite lignin from paper factories). Bacteriophage also may play a great role (Ganges, Nile). When taking in new drinking water aboard a ship (Wibaut-Isebree Moens, 1916) first bacteria develop.[116] Within a week they are cleared away by protozoa, leaving the water clear and harmless to health.

7.6.7 The succession on sterile soil: the lava problem

(Backer, 1929; Docters v. Leeuwen, 1936; Funke, 1943).[117]

In the so called Krakatoa problem, we meet with the initial vegetation on sterile lava. In our laboratory a method was conceived by Baas Becking, later by de Jongh and elaborated by Quispel (1938).[118] A "Zaponlac" film is prepared on top of (not too humid) soil and this film fixed by means of "Geisselthal-lack", after thorough drying the film is removed. (The method originated from the chance observation. While preparing plaster casts of the tracks of game animals, the author found a film of algae adhering to the plaster, which could be satisfactorily microscopied). The surface vegetation may now be studied *in situ*. Even clean white quartz boulders yielded fine preparations of moss protonema and *Zygogonium ericetorum*.[119] By means of this method Quispel found that, on sterilised lava at temperatures of 30 °C first diatoms and then moss protonema appears. The bluegreens come much later. It would be an excellent field of investigation to study succession *ab initio*. (To study the surface film of water, the same lack is used. A brass ring, suspended by 3 strings, is dipped into the lack and then held at the surface of the water) (see Fig. 7.15).

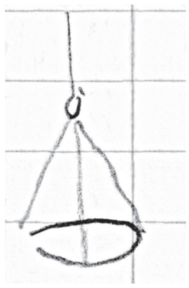


Figure 7.15 Sketch of brass ring suspended by three strings to study surface film of water.

A sterile lava is really the only habitat where we may speak about succession of organisms, as in other cases we always meet with simultaneous elements as well. This is also the case with plant succession, which are dealt with at length in the sociological works of Blytt-Sernander and of Braun-Blanquet. It is the hypothesis of Funke (1943) that these successions are just another expression of production and exchange of certain symbiotic substances, or the stimulation of certain bacteria, which may prepare the soil for the next phase.[120] In van Dieren (1934, *Organogenic Dune Formation*),[121] we first get the beach plants, adapted to moving sand, then

113 Baas Becking referred to the Wageningen microbiologist Nicolaas Louis Söhngen (1878-1934) and his research on "bodemmoeheid".

114 Refers to publications of Félix Hubert d'Herelle (1873-1949), French Canadian microbiologist and Frederick William Twort (1877-1950), English bacteriologist:
D'Herelle's short note in the *Comptes Rendus* in 1917 truly represents what can be recognised as the discovery of bacteriophage (D'Herelle, 1917). While an earlier report in 1915 by F.W. Twort certainly described a phenomenon (Twort, 1915), called "glassy transformation" (of bacterial colonies on agar) and "transmissible lysis", that was caused by bacteriophage in his cultures, Twort failed to interpret his observations in a way that encompassed the concept of virus, of intracellular parasitism, or of serial reproduction of an infectious agent, all of which d'Herelle proposed with clarity and experimental support in his short first note of 1917.
See Summers (2016) and Duckworth (1976).

115 Charles A. Kofoid (1865-1947) American zoologist. The reference is to Kofoid (1903).

116 Reference to Dr. Neeltje Louwrina Wibaut-Isebree Moens (1884-1965), who published in 1916 about the quality of surface water in and near Amsterdam (Wibaut-Isebree Moens, 1916).

117 Willem Marius Docters van Leeuwen (1880-1960), Dutch botanist and entomologist. Docters van Leeuwen (1936) wrote *Krakatau 1883-1933* in answer to Backer (1929), *The Problem of Krakatao, as seen by a Botanist*. For Cornelis Andries Backer (1874-1963), Dutch botanist. See for the *Krakatau Problem* Section 4.3.7a.

118 According to Quispel (1938) "Geiseltallack was used by geologists to make casts of fossils *etc.*"
In the 1953 version of *Geobiology* Baas Becking described the method as follows (p. 290):
Systematic measurements of surface tension of natural waters have not been carried out as far as the author is aware. Especially after a seasonal water bloom of bluegreens or a seasonal development of diatoms and Peridinians, such changes might be expected. The study of the water surface *in situ* has become possible by means of the spreading of solutions of plastics. (B.B., Java 1939, unpublished). When a thin brass ring is dipped in a solution of "Geisselthal-lack" and this ring (diameter ±5 cm), suspended by three threads, is carefully lowered on to the water surface, the area enclosed within the wire will be covered with a thin film in a fraction of a second. Then a glass plate may be placed under the film, which is lifted from the water. It separates quite easily from the brass ring and may be used in direct microscopy. In this way bacterial and algal colonies may be observed *in situ*.

119 Protonema is a thread-like chain of cells that forms the earliest stage (Haploid phase) of the life of mosses.

120 See for Funke (1943), Blytt-Sernander and Braun-Blanquet, Section 1.2.B.

121 Reference to van Dieren (1934). See also last section, Section 6.

the plants of the outer dunes, rich in lime sand, as the $CaCO_3$ is leached out, the plants of the lime-free, inner dunes, which culminate in a heather and the heather may yield to oak-birch forest. It seems logical that a concomitant change in the soil microbes should take place.

7.6.8 Plagues, parasites, epiparasites (see Lotka, 1924)[122]

[Baas Becking inserted Fig. 7.16. On top of the Figure: "Besemer."][123]

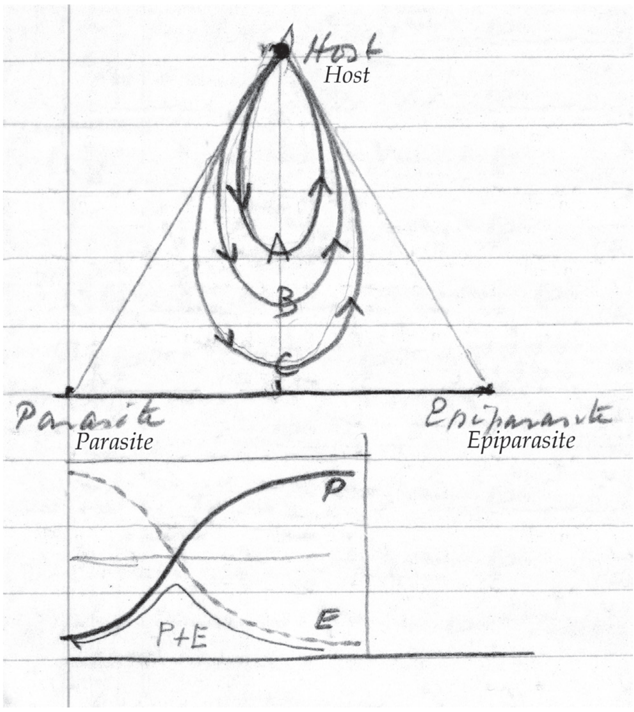


Figure 7.16 The equilateral triangular plot with compounds Host – Parasite – Epiparasite, is an example of controlling epiphytes and parasites by means of pesticides A, B and C. The second graph shows the controlling effect of epiparasites by parasites.

7.7 Parasitism etc.

7.7.1 Introduction

A parasite is chemically very helpless. In certain textbooks it is claimed that it cannot *e.g.*, synthesise its proteins, and therefore is so dependent upon its host. Now proteins are specific and as parent and host usually are phylogenetically totally unrelated it seems far fetched to claim any affinity between their proteins. Most probably the parasite has to break down the host's protein entirely and then start to build its own. For this breakdown as well as for this building it may miss chemical tools. It may miss the tools to break down sugar too. Therefore, a reinvestigation of the problem of parasitism by biochemical means seems promising.

7.7.2 Phage and serology

[Baas Becking left this section blank.]

7.7.3 Differentiation

A most remarkable characteristic of many parasites is their often far going dedifferentiation, which goes hand in hand with inability at chemical synthesis, which we consider to be the basis of parasitisation. The rule that morphological differentiation occurs at the price of chemical dedifferentiation has to be amended somewhat. The higher plant is morphologically and chemically highly differentiated (*MC*), the lower plant cell would be *mC*, the higher animal *Mc*, while the parasite should have a symbol *mc*. The dedifferentiation we meet in the parasites in the ticks (*Ixodes*), worms (*Taenia*), crustaceans (*Sacculina*), and many insects (*e.g.*, swallow fly). In plants this dedifferentiation is not so marked, although *Santalum*, *Cuscuta*, *e.g.*, show morphological regression. Dedifferentiation does not always accompany parasitism, however, not is it restricted to parasitism, as saprophytes (*Latraea*) and even epiphytes (*Taeniophyllum*) show morphological regression. It seems that in both cases the host cannot apply the variety of enzymes necessary for normal functioning.

7.7.4 Animal protozoa

Sprirochaetes. *Spirochaeta pallida* cannot be cultured on artificial media, on fresh blood substrates it is possible. What ergones are the cause of the phenomenon is not known. The live entirely in dissolved substances, as there is no mouth. *Amoebae* are capable of phagocytising; they live chiefly on bacteria. *Myxamoebae* have been cultured by Schure (Thesis, Leiden, 1935).[124] *Entamoeba coli*, *Councilmania lafleuri*, the latter cause of amoebial dysentery. The question remains whether they only accompany (and few upon) pathogenic bacteria. *Ciliates*. A great many ciliates are always present in the intestinal tract of animals. Pathogenicity is often indicated but extremely hard to prove, as the organism cannot be cultured. Certain free living ciliates have been cultured by Woodruff (1914 and 1921), *Flagellates*, *Lamblia internalis*, *Giardia* in man.[125]

7.7.5 Round worms

Leeches are provided with mycetomes. Many blood sucking organisms have mycetomes. Blood seems to be insufficient diet to them. Leeches secrete *hirudin*, a substance prohibitory to coagulation of the blood of a host.

Roundworms. *Ancylostoma duodenale*, mice worm,[126] *Oxyuris vermicularis*,[127] in the sphincter anus region, *Ascaris lumbricoides*, roundworm, in many mammals. Capable

122 Baas Becking mentioned A.J. Lotka also as a reference to epidemiology Section 5.9.13.

123 Reference to A.F.H. Besemer, botanist, studied in Leiden (until May 7, 1940), in 1941 to Wageningen as a plant pathologist. After WWII Extraordinary Professor in Phytopharmacy Wageningen. Baas Becking possibly referred to Besemer (1942), *Die Verbreitung und Regulierung der Diprion Pini-Kalamität in den Niederlanden in den Jahren 1938-1941* (PhD thesis Utrecht).
See also Besemer (1984).

124 Reference to Schure (1935a and 1935b). After WWII Petronella Sophia Joanna Schure did research on "Kresek", a bacterial disease of rice, at the Agricultural Station of the Botanical Garden at Buitenzorg.

125 Reference to Woodruff (1914 and 1921). By using natural pond water Woodruff was able to preserve the culture of *Paramecium* for several years. See also Darby (1930).
Giardia intestinalis, also known as *Guiardia lamblia*. First likely description in 1681 by Antonie van Leeuwenhoeck.

126 Probably *Heligmosomoides polygyrus*, previously named *Nematospiroides dubius*, a naturally occurring intestinal roundworm of rodents.

127 Present name *Enterobius vermicularis*.

of an oxybiosis, may be cultured outside the host. The dedifferentiation is not marked, structure as complicated as in free living *Nematodes*.

Tapeworms. *Taenia*, *Bothriocephalus*, have been kept alive in protein solutions of unknown composition.

7.7.6 Insects

Lice contain mycetomes. *Pediculus vestimenti* (typhus vector) [Baas Becking added a note: had I only known! 31-V-45]

Phthirus inguinalis,[128] *Pediculus capitis*.[129]

Flea Pulex irritans (plague vector *Yersinia*), mycetomes. [130]

Bugs. *Cimex lenticularis*, contains mycetomes. Bugs are probably vectors of many bacterial and protozoal diseases.

Tabanids.[131]

Mosquitos, *Stegomyia*, *Anopheles*.

7.7.7 Bacteria

Nearly all pathogenic bacteria may be cultured on artificial media. However, they are not strictly defined media, as one is made of blood cells.

Tuberculosis *B. tuberculosis*, [modern name *Mycobacterium tuberculosis*] many characteristics of actinomycetes.

Diphtheria. *B. loeffleri*,[132] many characteristics of actinomycetes.

Plague. *Yersina pestis*, semi treatment recently successful (Otten, 1936).[133]

Cholera. *Vibrio* cholerae. Semi treatment successful.

Typhoid. *B. typhorus*.[134] Semi treatment successful. See for literature on ergones A. Den Dooren de Jong, *Vakblad v. Biol*. 1942.[135]

7.7.8 Other cryptogames

Actinomyces, Madura foot,[136] may be cultured, although growth is slow (Lüske) [not identified]. Probably highly incompetent in synthesising milieu interne.

Dusts, fire, mildew

Skin fungus is usually cultured on saturated medium (malt extract + peptone Poulenc). Rijkebrinck [not identified] showed that protein may be replaced by ammonium salt. What ergones are needed is unknown.

7.7.9 Higher plants

Cuscuta.[137]

Loranthaceae.[138]

Santalales.[139]

Text box 7.5 – Baas Becking notes made prior to writing the manuscript

Feldmann (1930) collected sulphur in Turkmania brought back to Leningrad it burned holes in cloths and paper labels were destroyed; sulphuric acid occurred up to 5.16 % (desert Karakorum).[140]

7.8 Cycles

7.8.1 Component's life cycle and milieu cycle

Cycle and Metabiosis. A cycle is a sequence of phenomena which show recurrency. The old emblem of the snake with its tail in its mouth symbolises the cycle aptly. The cycle may be polar, one end representing aquatic life, the other terrestrial, or one side a high energy level and the other a low energy level. There may be components that are (temporary or permanently) removed from its influence ('slugs') but its recurrence is not broken by these processes. Cyclic processes suggest a sequence of events (See *Cyclic or succedaneous cultures*, Section 7.6.4). So, the circle itself may represents time (of day, of year, of month). The circle may also represent energy level, as in the case of the material compounds, centring around a certain element. But still, the time affect persists, as all these processes take time. In some cycles the links are strictly succedaneously in others, all acts are staged simultaneously. In some instances, the first link prepares the way for the second, and so on, until the circle (and the cycle) is closed. Then we meet with a real instance of metabiosis, as defined by H.G. Derx. But in this way the life cycle. In bacterial cycle and even the vegetation cycle may be linked, as in all cases there is dependence upon material exchange of a more or less definite nature.

7.8.2 Cyclic phenomena in general

In this section we shall deal with the so called "successions" of higher organisms first. They are too complex to be analysed as yet, they may only be described. Geochemically they are very important, as they determine the nature of the biosphere cover. We shall, furthermore, consider typical seasonal cycles

128 *Phthirus* [or *Pthirus*] *inguinalis* parasite of the human uro-genital tract, usually named *Pthirus pubis*.

129 Head louse *Pediculus humanus capitis*.

130 *Yersinia pestis* is a bacterium that can provoke septicaemic, pneumonic and bubonic plague in humans. The pathogen can be transmitted by infectious droplets or by contact with contaminated fluid or tissue or indirectly through flea bites.

131 See Baldacchino *et al.* (2014).

132 Diphtheria is an infection caused by the bacterium *Corynebacterium diphtheriae*. The German bacteriologist Friedrich August Johannes Löffler (1852-1915) was the first person to cultivate the bacterium.

133 Reference to Otten (1936). Otten's work with dead and live plague vaccine attracted much attention because it deals with the very fundamental question of the best and safest method of immunisation of human beings.

134 Epidemic typhus is due to *Rickettsia prowazeki*, spread by body lice, scrub typhus is due to *Orienta tsutsugamushi* spread by chiggers and murine typhus is due to *Rickettsia typhi* spread by fleas.

135 The reference is to the bacteriologist Louis Edmond den Dooren de Jong (1897-1972), den Dooren de Jong (1942).

136 Mycetoma is a chronic infection of skin and subcutaneous tissue. The condition was first described in the mid-1800s and was initially named Madura foot, after the region of Madura in India where the disease was first identified.

137 Possibly a reference to *Cuscuta howelliana* an abundant endemic parasitic plant that inhabits California vernal pools.

138 *Loranthaceae*, commonly known as the showy mistletoe. *Loranthaceae* are primarily xylem parasites.

139 Mistletoe is the common name for a number of parasitic plants within the *Santatales*.

140 Feldmann not identified.

(annual, monthly, diurnal) as they determine the majority of milieu influenced biological phenomena. Cycles of longer range we shall not mention here. In the third place we shall deal with material cycles. First of certain elements and compounds in their mutual relations, finally about three elements in particular: carbon, nitrogen and sulphur in which centre a great number of important geochemical reactions. Their relation to hydrogen, oxygen and electron transfer will be shown.

We further refer to Section 7.8.8 of this treatise.

7.8.3 Vegetation cycles and cyclic phenomena in agriculture

(Deli, three fallow system)

[Baas Becking inserted Fig. 7.17.]

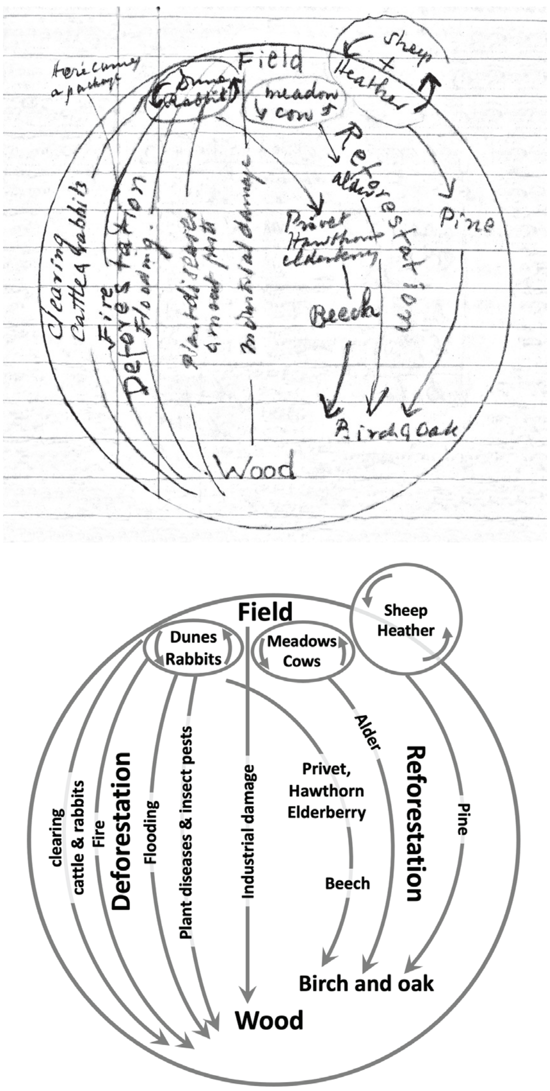


Figure 7.17 Vegetation cycle from Field (Dunes ⇔ Rabbits; Meadows ⇔ Cows; Heather ⇔ Sheep) to Wood by Reforestation and from Wood to Field by Deforestation.

As to agriculture and horticulture references should be made of alternation and fallowing and other recurrent procedures.

Further literature should be consulted. (Some of the more sensible plant ecology could be worked in here).

Forest is climax in our latitude. It should be stated which milieu condition, further the formation of grassland.

7.8.4 Annual and diurnal cycle, tides

[Baas Becking inserted Fig. 7.18.]

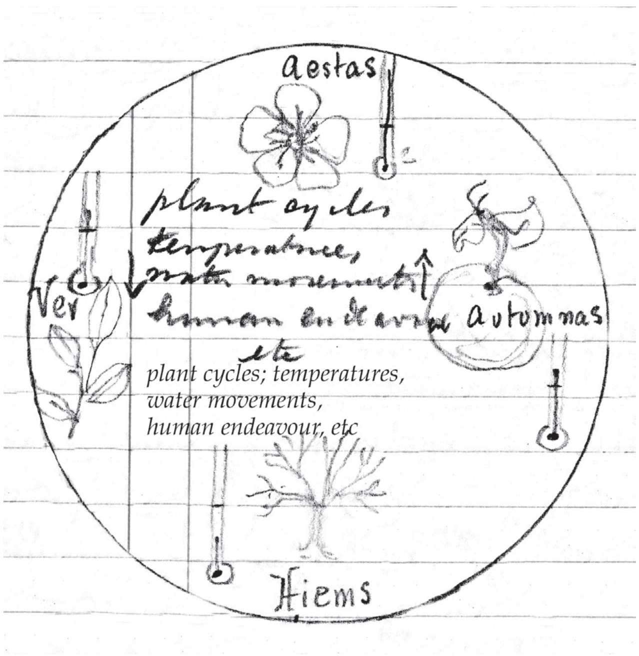


Figure 7.18 Cycle of four seasons (in Latin): ver, aestas, autumnus and hiems: spring, summer autumn, winter.

Diurnal cycles in plants, animals, man.

Annual cycles in plant, animal and man.

Diurnal milieu cycles.

Annual milieu cycles.

Tidal cycles (see therefore Section ---)

Tidal worms from Wilhelmshafen.[141]

Opening of stomata, purple bacteria, daily and annual rhythm in animal and human activity.

Cambial activity.[142]

This to be elaborated when the pertinent literature has been perused!

7.8.5 The cycles of elements (compounds)

"Des Menschen Seele gleicht ganz dem Wasser. Zum Himmel geht es, vom Himmel kommt es, und wieder nieder zur Erde muß es, ewig wechselnd" Goethe.[143]

a. Iodine. Kroprapport Nederland 1921 (iodine).[144]

b. Water. See *Geobiologie* (Baas Becking, 1934).

141 Probably a reference to a publication of the Wilhelmshafen team of the Senckenberg am Meer Institute concerning the Wadden Sea tidal flat ecology.

142 Cambial activity increases the girth of stems and roots by producing additional xylem and phloem.

143 Baas Becking gives a personal version of the first part of Goethe's Gesang *Der Geister über den Wassern* (1779). The original texts is as follows: Des Menschen Seele/ Gleicht dem Wasser:/ Vom Himmel kommt es,/ Zum Himmel steigt es,/ Und wieder nieder / Zur Erde muß es,/ Ewig wechselnd.

144 Baas Becking referred to Jossephus Jitta (1932).

c. *Iron*. See Correns (1939). Fe^{3+}, Fe^{2+}, porphyrium, $FeOH^{2+}$, ferrites, ferrates, and oxides FeO, Fe_2O_3, Fe_3O_4 and hydrated FeS, FeS_2.

***d. Oxygen*.**

Absorbed by weathering of rocks	(1)
Oxidation of FeS and FeS_2	(2)
Oxidation of organic matter	(3)
Respiration of animals and plants	(4)
Oxidation of other inorganic matter	(5)
Liberated	
By photosynthesis	(6)
By chemosynthesis	(7)

Balance see Section 5.12.4

Iron, minerals, haematite Fe_2O_3, limonite $Fe_2O_3.H_2O$, siderite $FeCO_3$, melanterite $FeSO_4.7H_2O$, magnetite Fe_3O_4.

[Baas Becking inserted Figs. 7.19 and 7.20.]

7.8.6 Carbon cycle[145]

To describe the carbon cycle in one page is tantamount to reviewing the largest part of the living, for carbon is the essential element of living beings. The starting point is the atmospheric CO_2, about the notation of which we refer to Figure 7.21 and Figure 7.3. The picture below is self explanatory. The highest reduction to methane, requires the donation of 8 electrons. This is the highest energy level of the cycle. In CO_2 assimilation only 4 electrons are transferred to the carbon dioxide. Humification and caramelisation are probably non-biological phenomena (see Section 3.12.3a, Section *Humus*). It is the question whether the universally occurring oxalic acid could not be derived from 2 CO + H_2O_2!

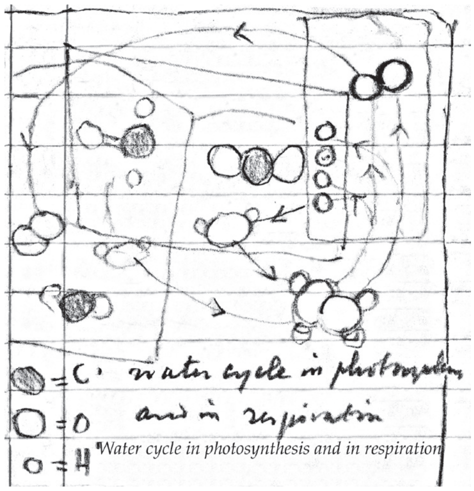


Figure 7.19 Rough sketch of the water cycle, atoms (H, C and O) and molecules (H_2O, CO_2, O_2) are depicted as circles. On the right hand side photosynthesis and on the left hand side respiration.

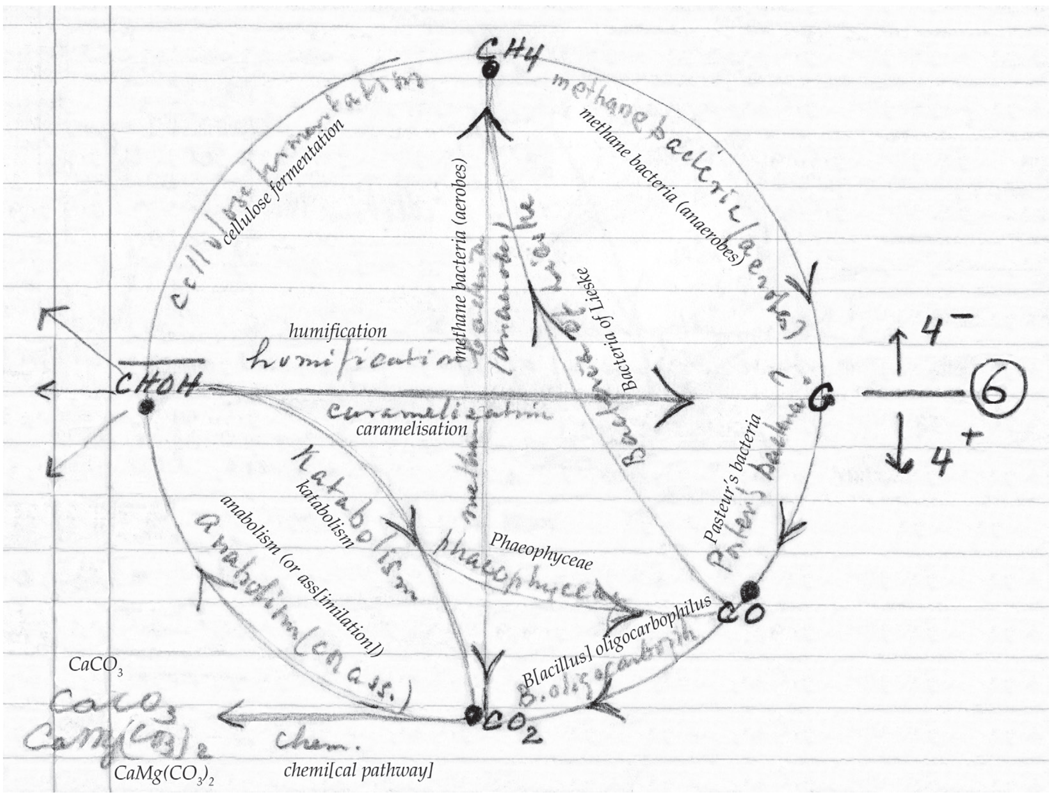


Figure 7.20 Carbon cycle.

145 Baas Becking described the Carbon cycle in Chapter VI of *Geobiologie* (1934), (p. 61-64 English edition) and on p. 653-660 of the 1953 manuscript of *Geobiology*. About "*Bacillus oligocabophilus*" he remarked:

> It is curious that Beijerinck was able to isolate an organism that can obtain its energy from the oxidation of CO to CO_2 and that there is sufficient CO present in laboratory air to obtain good quality cultures of "Bacillus oligocarbophilus" on a substrate consisting of tap water to which a small amount of phosphoric acid has been added.

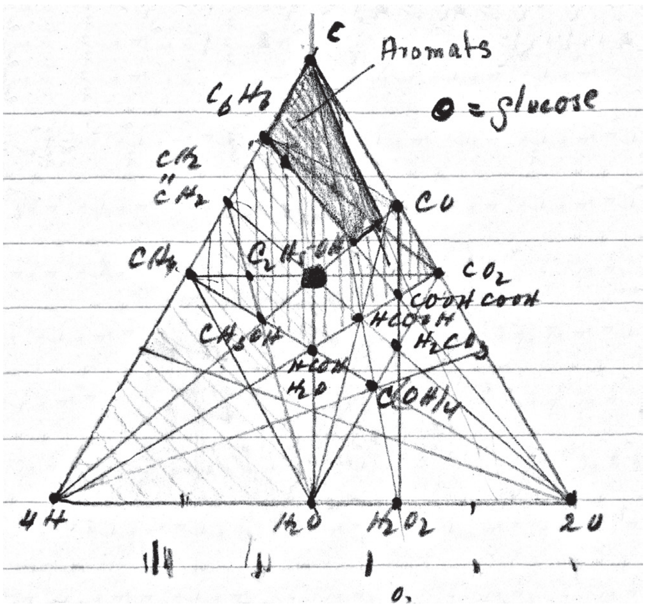


Figure 7.21 Equilateral triangular plot with compounds C – 4H – 2O, showing the oxidation and reduction state of components of the carbon cycle.

The energy relations as given in Plate 3.3 see Section 3.6.10.

There is only one such a diagram because C^{4-} and C^{4+} which oppositely changed, have the same valency. The existence of a C and a CO organism is questionable.

[Baas Becking further referred to Plate 3.1, see Section 3.5.15 in which the glucose breakdown is graphically represented. He also added Fig. 7.21 to the text.]

Maximally 4 molecules of water may be transferred to 1 CO_2, yielding methane CH_4. In CO_2 assimilation only 2 molecules of water are fixed upon CO_2 with the formation of 1/6 $C_6H_{12}O_6$. Here the C is half reduced. To the transfer of every two electrons then correspond 1 molecule of water. In order to find the reduction state (n of I electrons transferred on C^{4+}) we use

$$\frac{4n_c + 14H - 2a_0}{n_c} = R$$

This number, multiplied by 28,200, (1/2 ΔH, H_2O) yields the heat of combustion (approx.) of the compound (see Plate 3.2) It is of course improbable to mention here the components of the carbon cycle. They embrace the large part of biochemistry. Only a few specific remarks should suffice.

1) Porter (1926) has claimed to have found an organism oxidising C.[146] Coal on heaps loses 10 % of its weight in one year. This may also be inorganic (pyrophonic iron) However, process seems to stop after application of disinfectants.

2) CO, the presence of CO ergones by no means proven.

3) CH_2=CH_2 may become very important! Ripening of fruit *etc*.

'Slugs' in the cycles.

There remain in the cycles compounds that do not enter the cycle again readily, or only when certain conditions are fulfilled. Some of these products and their conditions are:

Table 7.5 Slugs of carbon, nitrogen and sulphur in the cycles.

Cycle	Product	Mobility factor
C	Coal peat, oil, chitin	Oxygen, ?
N	Guano, caliche	Water
S	Sulphur	Water, oxygen
	FeS, black mud	Oxygen

7.8.7 Nitrogen cycle[147]

[Baas Becking inserted Fig 7.22.]

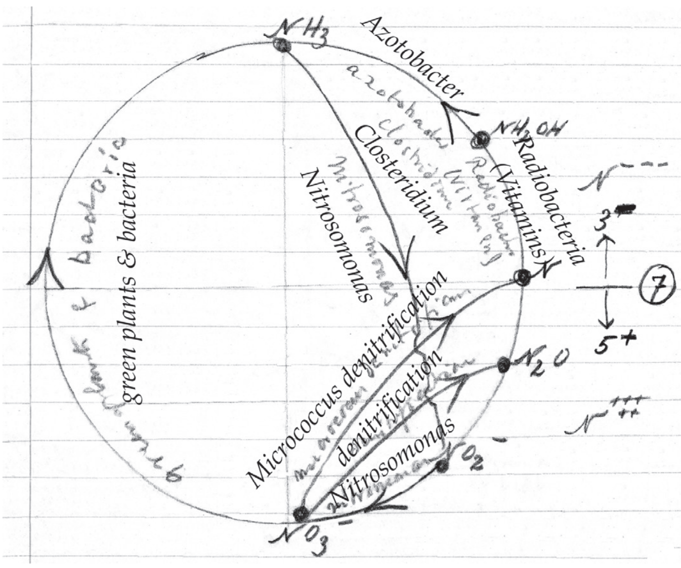


Figure 7.22 Nitrogen cycle.

Clarke (1916, *Geochemistry*) assumes that all of the organic nitrogen should be derived from the atmosphere. Fixation of the nitrogen starts the cycle. There are, as stated at other places in this treatise, a symbiontic aerobic *Radiobacteria*, further and independent aerobic *Azotobacter* and an anaerobic *Closteridium*, a butyric acid ferment and a few *Cyanophyceae*, *Nostoc*? *Oscillatorium*, all able to reduce the nitrogen, probably all with the aid of molybdenum as a catalyst. The efficiency of the *Azotobacter* is much less than the Haber Process (Baas Becking and Parks, 1927). Probably hydroxylamine is an intermediary compound. Further we find, as an autotroph Winogradsky's *Nitroso*- and *Nitrobacteria* (Kingma Boltjes, 1934) proved that they are facultative heterotrophs) and denitrifying, producing N_2 and N_2O from NO_3. The green plant and various bacteria are capable to reduce NO_3^- to NH_3. The NH_3 enters either keto acid, to form, *via* immuno- and amino oxides, the aminoacids (Martius and Knoop, 1937) or they are accompanied by oxal acetic acid (vitamins) to form asparagin and glutamin (Chibnall, 1939).[148]

146 Reference to Porter (1925). Charles Walter Porter (1880-1971, Professor of Chemistry University of California, Berkeley (1925-1946). Baas Becking probably was acquainted with Porter.

147 Baas Becking described the nitrogen cycle in Chapter VI of *Geobiologie* (1934) (p. 64-65, English edition). In the 1953 manuscript of *Geobiology* Baas Becking described the nitrogen cycle on p. 668-672.
See for recent review of the Nitrogen Cycle (Thamdrup, 2012).

148 See for Kingma Boltjes (1934) Section 4.7, for Martius and Knoop (1937) Section 7.1, and for Chibnall Section 3.9.1.

In the reduction eight electrons are again added to N^{5+}. The composition of the biologically important H, N, O compounds are given in the two diagrams, constructed for N^{3-} and for N^{5+} respectively (see Fig. 7.23a and 7.23b). As the energy relations are particularly complex, they are not included in the diagram. The line N-H_2O probably represents the area of lowest potential. In the lower triangle the reactions NH_3 to HNO_2 and HNO_2 to HNO_3 are given as hydrogenation of ammonia, resp. nitrous acid (see Fig. 7.3a and 7.3b). The nitrifiers have an efficiency of ±5 %.

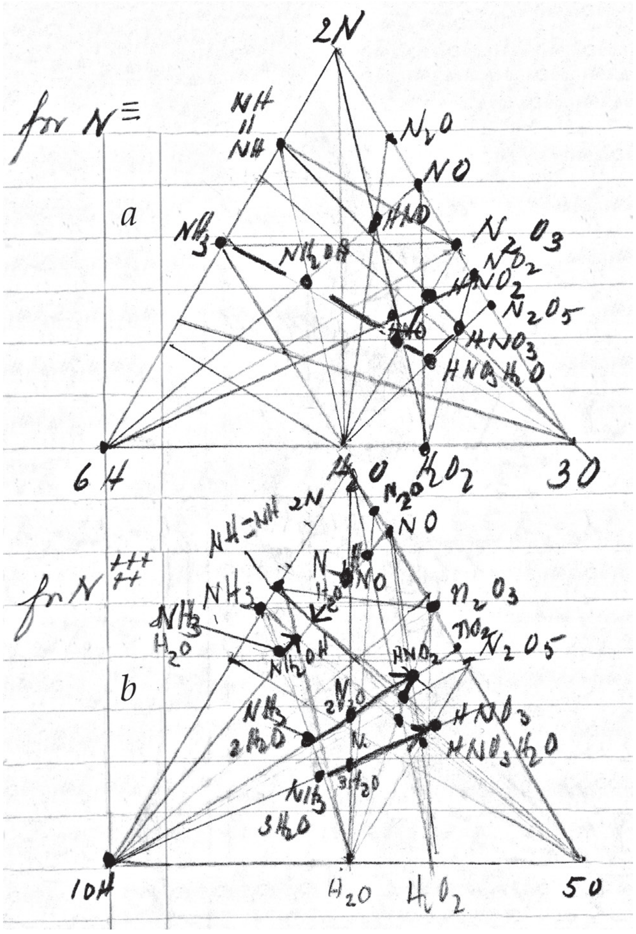


Figure 7.23 Equilateral triangular plots with compounds N – H – O, showing the oxidation and reduction state of N^{3-} and N^{5+} components of the nitrogen cycle.

$$\left.\begin{array}{l} NH_3 + 2H_2O \rightarrow HNO_2 + 6H \\ HNO_2 + H_2O \rightarrow HNO_3 + 2H \end{array}\right\}$$

$$(Mo) + N_2 + 2H_2O + H_2 = 2NH_2OH$$

$$(?) + 2NH_2OH + 2H_2 = 2H_2O + 2NH_3$$

As far as nitrogen fixation is concerned, the diagram for N^{5+} gives this in terms of hydration and dehydrogenation of N_2, taking hydroxylamine as an intermediary product. As nitrogen has very little affinity for water, the above equations are a good example of paper chemistry, however.

[In the margin:] The book of Correns (1939, p. 241) recognises only the aerobic part of the nitrogen cycle and the conclusions for N^{5+} reaction about the Zechstein are unwarranted.

7.8.8 Sulphur cycle[149]

[Baas Becking inserted Fig. 7.24.]

Geochemically most abundant is the sulphate, we shall start with that compound. It is reduced back by green plants and by anaerobic bacteria to sulphide ion, which on exposure to the air yields free sulphur. But H_2S, aerobically may generate S by autotrophic aerobes.[150] Anaerobically, the reaction is endothermic, and the organisms which perform this feat are photosynthetic (purple and green bacteria). While the reaction $H_2S + O = H_2O + S$ is chemical, the reaction $S \rightarrow SO_4^{2-}$, is mainly biochemical. In this reaction aerobic autotrophics may go as far as a thiosulphate, but usually (*Thiobacillus thiooxidans*)[151] they go the whole road to sulphate, of the forming free sulphuric acid. In the green plant we find sulphur as thiocyanate, mercaptum[152] or disulphite sulphur and in aminoacid.

The triangles in Figure 7.25 refer again to S^{2-} and S^{6+} respectively. In the complete reduction 8 electrons are again added. The energy relations are opposite to those in N_2, S being the highest level, as illustrated in the overall triangle in Figure 7.25.

$$H_2S.H_2O \rightarrow S.H_2O + 2H$$

$$2\ SH_2O + H_2O \rightarrow H_2S_2O_3 + 4H$$

$$2\ SH_2O + 4H_2O \rightarrow 2H_2SO_3 + 8H$$

$$SH_2O + 3\ H_2O \rightarrow H_2SO_4 + 6\ H$$

$$\overline{H_2S.4H_2O \rightarrow H_2SO_4 + 8H}$$

Sulphide oxidation and sulphate reduction may be both represented by hydrations and dehydrogenations or the inverse, as seen from the diagram and from the accompanying set of equations. The excellent paper by Bunker (1936, *Ministry of Publ. Health reports of the United Kingdom*) should be consulted and the various organisms noted.[153] The energy efficiency of sulphur bacteria is again low (5%). It is worthy of note that the sulphate reducer, when grown

149 On March 26, 1938 Baas Becking gave an address on the sulphur cycle during the fifth scientific meeting of the Dutch section of the International Society of Soil Scientists (Baas Becking, 1938b). See Baas Becking *Geobiologie* (1934), Chapter VI (p. 65-67 English edition, 2016); Baas Becking manuscript *Geobiology* (1953a, p. 661-668).
See also for the present state of the art of research on the Sulphur Cycle. Jørgensen (2021).

150 Baas Becking used the word "philothion" in Figure 7.24 of the sulphur cycle. It referred to the finding of J. de Rey-Pailhade (1888, *Comptes Rendus Acad. Sci.* 106, 1683-1684) of a compound capable of producing hydrogen sulphide from sulphur powder. Nowadays known as reduced gluathion (GSH), present in most living cells from bacteria to mammals (except some bacteria and amoeba).

151 Present name *Acidithiobacillus thiooxidans*

152 Thiols are sometimes referred to as mercaptums.

153 A reference to Henry James Bunker (1897-1975) and his review of sulphur bacteria in Bunker (1936).
Bunker's specialty were the bacteria of the sulphur cycle, his research material being at first Thiobacilli and later the sulphate reducing bacteria. The sulphur bacteria were then a rather neglected group, studied mainly in Holland, and Bunker's review collected together the scattered literature and laid the foundations for developments in this area after the Second World War. His review is perhaps the most recondite of Stationery Office publications to have achieved a second edition: it was reprinted in 1951. The sulphate reducing bacteria were then among the most awkward of the sulphur bacteria to handle, yet they showed the widest range of economic activities, one of the most dramatic of which was their role in the corrosion of buried pipes.
See Postgate (1976).

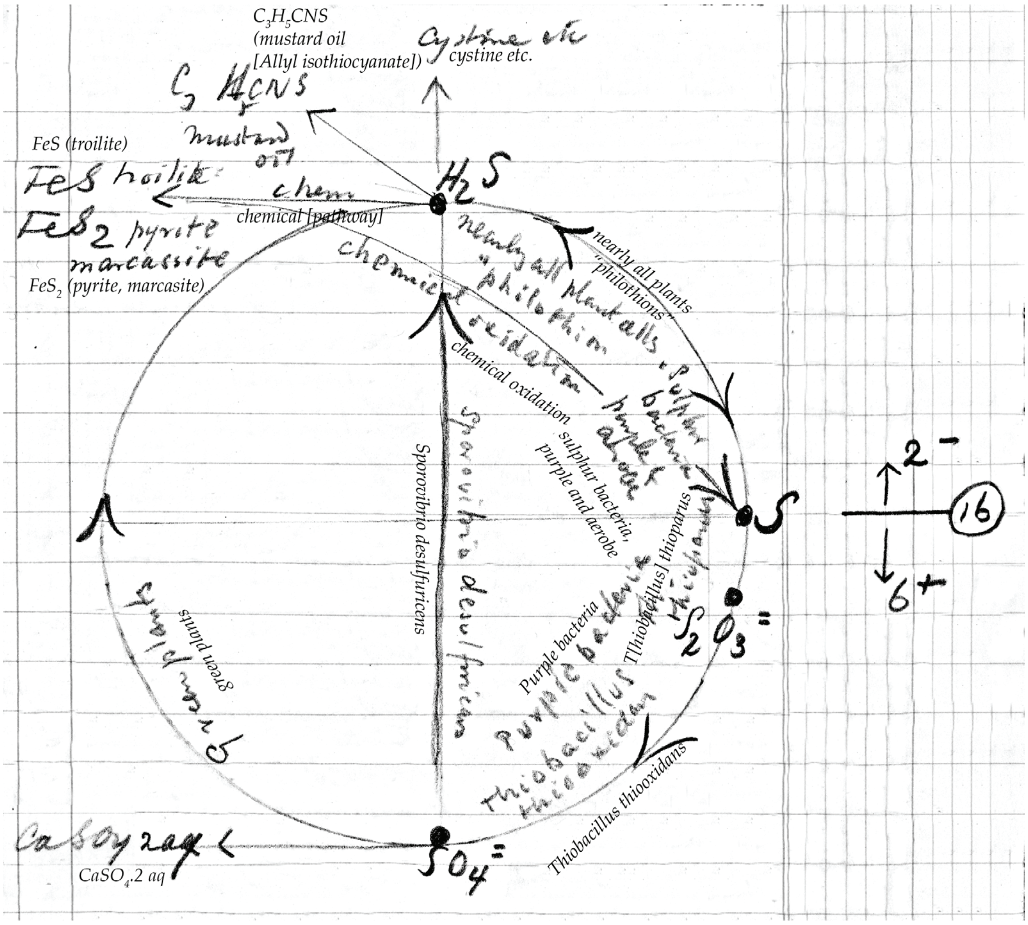


Figure 7.24 Sulphur cycle.

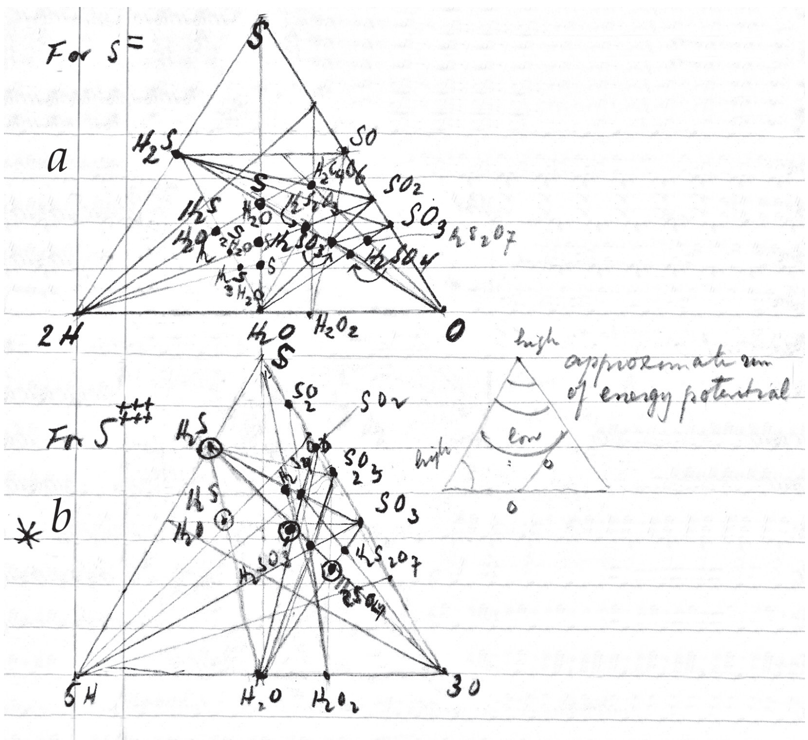


Figure 7.25 Equilateral triangular plots with compounds S – H – O, showing the oxidation and reduction state of S^{2-} and S^{6+} components of the sulphur cycle.

on a substrate containing only mineral salt and hydrogen, behaves as an autotroph (D. Stephenson,[154] compare the work on the corrosion of iron pipes of von Wolzogen Kühr).[155]

Sulphate reduction makes oxygen available, and the oxidation of $S \rightarrow SO_4$ is concomitant with the reduction of CO_2! However, as the efficiency of these autotrophs is only 5-10 % the geochemical balance will not be disturbed materially by these processes. Other sulphides, such as those of zinc and copper, may very well originate in a similar fashion as the FeS, and also the oxidation of these sulphides to sulphate may be bacterial (see Section 5.8, *Minimum Elements*) From all bacteria living in the organic substrates, the sulphur bacteria probably are geochemically the most important. Their action, especially in the ocean, has been described (see Section 6.4.4). Consensus of opinion among geologists exists as to the large sulphur deposits (Sicily, Louisiana) as of being of biological origin. Much sulphate (gypsum) should also be of microbiological origin, despite the dictum of Correns (1939), that all of the gypsum is marine in origin.

7.8.9 Summary and conclusions

Green plants and chemosynthetic bacteria function as the only inorganic reductants, but the quintessence of this function lies in the power to photolyse or to electrolyse *water*, to reduce the hydrogen oxide! Here the electron has to be fixed into the H^+. In the case of metallic iron in the soil this process may be understandable ($Fe + 2H^+ \rightarrow Fe^{2+} + 2H$), but when there is no electric element the mechanism of the process remains obscure. It also may be that the electron moves from OH^- to H^+ according to

$$2H^+ + 2OH^- = H_2 + H_2O_2$$

It may be that there is still a deeper relation between the heat of formation of water and the energy values of organic compounds (Plate 3.1 and Plate 3.2). It seems that ½ of the energy is necessary to add one electron to a cation. The matter still requires looking in to further (L. Pauling, 1939, *The Chemical Bond*).[156]

Cycles of C, N and S are a series of dove tailoring oxido-reductions, endo- and exothermic, each linked with its organism or groups of organisms, a veritable exposé of metabiosis, of succedaneous symbiosis.

7.9 Biocoenosis

7.9.1 Introduction

A biocoenosis is a natural community consisting of various vital components. Biocoenosises may be, like organisms, autotrophic or heterotrophic.[157] Whenever they are self supporting (containing a preponderance of autotrophic components), they form a real closed community. Heterotropic biocoenosises may never be understood without taking into consideration their source of energy. The biocoenosis may be, therefore a closed universe, repeating on a small scale the story of the biosphere in its entity. However, milieu conditions are now specialised and the natural milieu is much narrower than that on earth. Our milieu of the biocoenosis should be specific enough to characterise the organisms expected to live here. The simultaneous occurrence, on the other hand, of several specific organisms characterises a specific biocoenosis. By the organisms found in a brine lake one is able to predict (within bounds) the chemical composition of its waters, while, when knowing H and S analysis, one is able to predict the occurrence of its inhabitants.

7.9.2 "Closed universes"

In 1925 the author enclosed in a quart bottle some natural brine of approx. 20 %, containing the eggs of the crustacean *Artemia*, the unicellular alga *Dunaliella*, various protozoa and bacteria. The bottle was ¾ filled and hermetically sealed. The community remained active for over four years, having yielded countless generations of *Artemiae*. After that time the bottle was filled with a dense sediment, the skins of these *Phyllopods* consisting of chitin which, apparently could not be decomposed with sufficient velocity. A sample of freshwater from a dune lake, containing *Ostracods* and bluegreen algae, collected 1937, remained active for 3 years. Here again the chitin accumulated. The study of these "polycomponent" systems still yields results not amenable to analysis, but if two or three component systems were studied, one could, by increasing the complexity step by step, probably arrive at a much better understanding of natural biocoenosis (see Beauverie and Monchal, *C.R.* 1932, 195).[158] The *aquarium* is, in a way, a closed universe, as Warrington[159] and especially J. v. Liebig have recognised (Liebig, *Die Welt*).[160] By a universe we

154 Reference to Stephenson and Strickland (1931).

155 Reference to Von Wolzogen Kühr (1923a, 1923b, 1937), Von Wolzogen Kühr and van der Vlugt (1951).

156 Reference to Pauling (1939). See also Section 2.5.15.

157 In the 1953 version of *Geobiology* Baas Becking remarked about the biocoenosis (p. 591):

> A biocoenosis represents a polysymbiotic relation. Symbiotic relations are, to large extent, relations of 'give and take.' The great advance in the *Neurospora* research has done much to strengthen this belief. Loss mutations may account for a great many relations, but we should not forget that there are organisms which probably never possessed certain powers, necessary for their maintenance and their development and that these organisms, therefore, are "chronically" dependent on others.

On p. 635 of the 1953 *Geobiology* manuscript Baas Becking wrote in eloquent style:

> If words are comparable to organisms, sentences should be like the biocoenoses, like living communities. We may also use another simile, that of music, where we have notes and musical phrases. Here the blending of the simultaneous and the successive is known in one form of music; the canon.
> The biocoenosis, moreover, reminds us strongly of the 'belles lettres', for it is a story of mating, begetting, competitive maintenance, of dissipation and of farewell, both successive and simultaneous phases being represented. A biocoenosis of more than two components is already difficult to analyse. In still more complex cases we must often be content with descriptive or theoretical treatment. If we realise certain relations, we are prone to enlarge, and enlarge upon, their importance. If we cannot account for certain phenomena, we either allow them to stay unaccounted for (and many are the questions raised by our scientific ancestors which we treated with such neglect), or we may invoke "chance" (when mechanistically inclined) or "directed forces" (when vitalistically inclined) to take care of those, still indigestible, morsels. The great system of nomenclature, developed to describe the natural communities is very often but a cloak to hide our ignorance.
> Metabiosis finds its highest expression in the biocoenosis, but metabiotic relations are of multiple nature and may be traced in many more elementary substrates.

158 Jean Jules Beauverie (1874-1938), French botanist and mycologist. See also Section 7.1.

159 Reference to Robert Warrington who presented early experiments with self supporting systems in aquaria in 1850 to the British Chemical Society: 'On the adjustments of the relations between animal and vegetable kingdoms, by which the vital functions of both are permanently maintained.' He placed two goldfish in 20 gallons of spring water, which half filled a glass bowl. Some sand, mud, pebbles and bits of limestone were added to the bottom of the bowl. The mud was used to hold the roots of *Vallisneria*. Warrington left the aquarium undisturbed until a green scum started to coat the wall of the bowl, obscuring the view of the goldfish. The addition of some snails, which fed on the green scum and decaying vegetable matter resulted in clearing the water.

160 Reference to Justus von Liebig (1803-1873), German chemist. Liebig demonstrated during popular lectures in the Aula of the Munich University a Warrington closed aquarium system. Liebig had set up an aquarium for Queen Maria von Bayern (1811-1864), a "Liebigsche Kleine Welt im Glase" for her Salon in the Munich Royal Palace.

mean a part of the biosphere, where creative and destructive metabolism (catabolism and anabolism), Shiva and Vishnu,[161] are both active.

7.9.3 The aquarium at Amsterdam

The Amsterdam Zoo Natura Artis Magistra contains several sea water aquaria, constructed in 1900 and in 1933 studied by Catharina Honing.[162] The aquarium is an ideal biocoenosis to study and has been used quite often as an example of natural cycle. The Amsterdam sea water aquaria contain copepods in the water which is derived from the conduits. Due to the oligodynamic action of these copepods the flora is extremely limited. There is, therefore, the fauna and the food, together with a filter system of sand, and an aeration system. Anaerobiosis apparently does not occur (only small patches of black mud observed), but necessary reduction processes are also hindered. Deficient in the cycle is denitrification. There is an accumulation of nitrate, due to the fact that the "salpetre micrococcus" of Beijerinck cannot perform its function, as the oxygen tension is too high, due to continuous aeration.

7.9.4 The black mud

The community of the black mud, FeS, troilite imbedded in silt, clay or sand is characterised by an extreme anaerobiosis. The community consists of the *Sporovibrio desulfuricans*,[163] cellulose bacteria, *Clostridium*, of green organisms, certain bluegreens (*Phormidium*) and *Euglenids* (*Eutreptia viridis*), further several protozoa and nematodes. The origin of the black mud is not as Hecht (1933) and Correns (1939) still seem to believe,[164] the decomposition of proteins as Dorothy Stephenson has raised, *Sporovibrio* as hydrogen and energy source.[165] The author of this essay found most copious sulphate reduction in perfectly inorganic media (Melianthus [?] solution) with finely divided filter paper. Here cellulose fermentation sets in first and the sulphate reduction liberates as the fatty acid produced (Baars, 1930), or as the hydrogen produced. Metallic iron as Wolzogen Kühr showed,[166] forms, with the soil solution an electric element, giving rise to iron ions and free hydrogen. The latter yields the energy needed for the reduction of the SO_4^{2-} according to

$SO_4^{2-} + 8H \rightarrow 4H_2O + S^{+}$ preceded by $Fe + 2H^{+} \rightarrow Fe^{2+} + 2H$.

The third reaction being $Fe^{2+} + S^{2-} \rightarrow FeS$

See further Section 2.3.2.

As soon as oxygen is admitted an entirely new biocoenosis appears also when light is admitted. Pyrite FeS_2 is of secondary origin according to $FeS + S = FeS_2$ (Verhoop, 1940) and is of non-biological origin. The black mud may be one of the largest 'oxygen traps' on earth, as during oxidation large quantities of $2FeS + 3O \rightarrow F_2O_3 + 2S$ oxygen are fixed. [167]

[In the margin: The community is dependent, in most. It needs hydrogen as fuel and therefore usually, organic food.]

7.9.5 Thermal springs

1. Amoebae.
2. Diatoms.
3. Flies.
4. Beetles.
5. Bluegreens.
6. Sulphur bacteria.

7.9.6 Ocean brine

a) *Ruppia maritima* ~~(Walfish Bay!)~~.[168]

b) *Artemia*.[169]

c) *Dunaliella – Ephydra*.

Artificial brine (Boekelo).[170]

161 Hindu Gods: Shiva (destroyer) and Vishnu (protector).

162 The Amsterdam Zoo 'Artis' has a seawater aquarium since 1882. Unique to the ARTIS Aquarium is the William Alfred Lloyd water filter system that is still working today. With its masonry and tube labyrinth, this system has been supplying the entire Aquarium with naturally filtered water for almost 140 years, which makes fresh and saltwater life possible in the more than 60 different aquariums.
In *Geobiologie* (1934, p. 176), Baas Becking referred to the Amsterdam PhD thesis of Catharina Honing (1933), *Onderzoek over de Reiniging van Zeewater in Groote Aquaria*.

163 Present name: *Desulfovibrio desulfuricans*.

164 In Section 6 Baas Becking referred to Hecht (1933). Reference to Correns (1939, p. 209-210).

165 Baas Becking referred not to Dorothy Stephenson but to Majory Stephenson (1885-1948), British biochemist, who wrote the classical textbook *Bacterial Metabolism* in 1930. Baas Becking referred to Stephenson and Strickland (1931). See also Sections 4.8 and 7.8.8.

166 See for reference to research of Wolzogen Kühr, Section 7.8.8.

167 Reference to Verhoop (1940). See also Section 6.
In the 1953 manuscript of Baas Becking remarked (p. 666-667):
Verhoop (1940) gives a colour scale of various blackness, corresponding to natural muds. The "palest" mud, where the FeS may just be discerned, corresponds of 0.1 mg FeS *per* kg soil mud, where the FeS may just be discerned, corresponds of 0.1 mg FeS *per* kg soil, 18 % moisture. This would mean about 0.1 γ *per* cc. The blackest mud corresponded to 320γ/cc sulphur. The values assumed for the "terrestrial" intensity of the sulphate reduction are of the same order of magnitude. In oxidation of this reduces sulphur, 4 x 10^8 tons of oxygen would be fixed. Inasmuch as the total oxygen in the atmosphere amounts to 1.2 x 10^{15} tons, the sulphate reduction cannot, except locally influence the oxygen tension on a large scale.

168 'Walvis Bay' in Namibia, a safe haven for sea vessels, rich in plankton and marine life, attracting large numbers of southern right whales. *Ruppia maritima* is an estuarian pondweed in Walfish Bay. Baas Becking possibly referred to Brongersma-Sanders (1943).

169 Oren (2011, p. 21-22), discussed Baas Becking's fascination for the brine shrimp *Artemia*.

170 In the 1953 manuscript of *Geobiology* Baas Becking referred to the Boekelo research (Nicolai and Baas Becking, 1935) (p. 136-137):
There are rare as well as common microbes. But usually the forms will fill their "niche" in a surprising short time. A case in point is the salt bath of Boekelo, in Holland. The salt in Boekelo is obtained by pumping water into the subterranean layers of salt and pumping up the brine. In 1934, exploitation of the pool was started, after infection with seawater. In August of that year the author could find, however, no specific marine organisms in the pool. A few microbes typical of strongly saline solutions were present. In the last days in August 1934 a mass development occurred of a rotifer, a *Brachionus*, approaching closely in form the *Brachionus* described from the salt lakes in Siebenbürgen and found by myself in Soda Lake, Nevada, 1924.
Soda Lake was conspicuous for the mass development of brine flies (*Ephydra* sp) the pupae of which formed veritable floating islands (they are roasted and eaten by the Indians). While this fly did not occur at Boekelo in 1934, it suddenly made its appearance, in such masses that it hampered the use of the bath. The closest "saline" stations were; Greifswald (Pomerania, near the Baltic), Mulhouse (Lorraine) and Staffordshire (England). It seems most probable that a complete biocoenosis, corresponding to the chemical composition of the milieu, would have been completed in due time.
See for Boekelo also Section 4.3.9.

7.9.7 Desert brine

a) *Lochmiopsis – Brachionus.*

b) *Dunaliella – Ephydra.*

Varves.[171]

7.9.8 Heatherpool

Varves.

7.9.9 Mono lake

[See also *Geobiologie,* 1934, p. 110 English edition, 2016.]

Varves.

7.9.10 Caves

[Baas Becking left this section blank.]

7.9.11 Disturbed equilibria

Zuyderzee, Walfish Bay, phosphate H_2S, O_2, salinity, N.W. Polder, Zurich See (see Minder, 1943).[172]

[Crossed out: 12 Deep Sea.]

7.9.12 Meadow land

[Baas Becking left this section blank.]

7.9.13 Sea clay

[Baas Becking left this section blank.]

7.9.14 Higher organisms

Definition of biocoenosis.[173]

Plants.

7.9.15 Higher organised animals

Proverbs 31:25 The ants are a people not strong, yet they prepare their meat in summer.

Ant-plant!

7.10 Summary and Conclusions

[Baas Becking left this section blank.]

171 In the 1953 version of *Geobiology* Baas Becking remarked (p. 298):

> In the sediments the lake writes down its history. In desert lakes as well as in glacial lakes sediments are often "varvate", *i.e.* laminated and stratified. If the annual season contribution be known, measurements on sediment will give a clue to the previous history of the lake. Important "markers" are the aeolic pollen grains. Their nature and frequency in a so called "pollen diagram" may yield important clues as to the age of the deposit. This is particularly important in lakes of glacial origin as the Wisconsin Lakes and the Connecticut Lake 'Linsley Pond.'

172 See for Zürich See and Minder, Sections 5.9 and 8.5.5. For Walfish Bay see Brongersma-Sanders (1943) and Section 5.12.3. 'N.W. Polder' [Noordwestpolder]; initially the name for the present Wieringermeerpolder, newly created land, developed in the 20th century by draining parts of the inland Zuiderzee. Draining was completed in August 1930. After desalinisation the new land became usable in 1934. See Baas Becking (1936a, 1936b).

173 See Sections 7.9.1 and 7.9.2.

8. MAN AND THE TERRESTRIAL MILIEU

Text box 8.1 – Baas Becking notes made prior to writing the manuscript

R.G. Stapledon. *A Survey of the Agriculture and Waste Land of Wales*, 1936, p. 9: "The toxic above all others which this nation with its large population of unemployed, its excessive wasting of energy in non-creative enterprises, and in morbid pursuits needs, is the stimulation of well organised and well planned land improvement carried into every parish of Great Britain."

W. Davies (in the above), Wales huge wood destruction by man and cattle.[1]

1874, Marsh G.P. Influence of the forest on floods (*The Earth as modified by Human Action*, N.Y. 1874): "The vengeance of nature for the violation of harmonies, though slow, is sure."[2]

8.1 Man as Shaper of the Milieu

8.1.1 Introduction

Isaiah 24:5 The earth is also defiled by the inhabitants thereof.

Man is such a powerful shaper of the milieu, such a prominent agent in the moulding of the earth's surface, that his influence should merit a study apart. This study would be exceptionally sordid, which, leaving after a short time, a misanthropic student. Man is a shaper of the milieu, fortunately he cannot transcend this milieu and he is equally influenced by it. In the first place because he is an important member of a coenobiosis, which coenobiosis has to prepare his vitamins, part of his hormones and enzymes and even his visual purple. Furthermore, although he may be as pale as a cavern axolotl, he needs ultraviolet light to activate his sterol to vitamin D. Without extraneous help, other than clothing, he cannot persist at a very high temperature. He needs a certain oxygen pressure and a certain total pressure. Also, a certain humidity. He needs caloric food, mineral food and rare elements. The water, which he drinks, he has to titrate with his gastric juice and he gets accustomed to his own type of drinking water. He is very susceptible to disease by infection. He is parasite ridden. And there are unknown factors in the milieu, still threatening. What we can ascribe to dental caries, baldness, inflamed nostrils, small toes, or to such rare serious threats such as cancer? Males and females, unlike other mammals remain alive for a considerable period after sexual activity, without becoming too socially disagreeable.

We need, a number of ergones of which we know only a few, which we call vitamins. Probably we need a vast number of ergones, and if we knew them all, man could get their brain back, and there would be no dental caries. We have probably an unlimited belief in ourselves and have built our surroundings claiming that they completely furnished us with all the comfort we needed. But we overlooked some of the primary essentials, apparently.

We want;

8.1.2 Deforestation and burning

(Lane-Poole (1911), van Steenis).[3]

Joshua 17:18 The mountain shall be thine; for it is a wood, and thou shalt cut it down; and the outgoings of it shall be thine.

Woods are abhorred by primitive man.

8.1.3 House building

Clothes extend the function of the skin in active man, the inactive cell needs a heavy cyst wall, this is the house.

8.1.4 City building

Man's social instinct is too weak to allow for a voluntary socium. Always there should be a Mount Sinai and tables of the law.

8.1.5 Road building

[Baas Becking left this section blank.]

8.1.6 Industrialisation

[Baas Becking left this section blank.]

1 Sir Reginald George Stapledon (1882-1960), agricultural scientist. In 1919 appointed as the first director of the Welsh Plant Breeding Station. William Davies (1899-1968), botanist and grassland specialist. He was member of the staff of the Welsh Plant Breeding Station since 1923, between 1933 and 1940 he was Head of the Department of Grassland Agronomy. A survey by Davies of the grassland and waste lands of Wales was published under the editorship of R.G. Stapledon in 1936.

2 George Perkins Marsh (1801-1882), American diplomat and philologist, who recognised as one of the first the irreversible impact of man on the earth. Baas Becking referred to Marsh (1874) published book, *The Earth as Modified by Human Action*, which was a largely rewritten version of his 1864 published *Man and Nature*.

3 Reference to Lane-Poole (1911), *Report on the Forest of Sierra Leone*. C.E. Lane-Poole was employed by the British colonial government of Sierra Leone to evaluate the state of the country's forests. In his report he noted areas of forest destruction on the Peninsula, placing blame directly on the 'inefficient' and 'destructive' activities of the native population; with a particular emphasis on the Temne sawyers and canoe makers. In contrast, the logging activities of Europeans along the Peninsula were not criticised. Lane-Poole was also virulent in his criticism of the natives shifting cultivation farming methods, which he deemed to be wasteful. Fundamentally the rhetoric in these reports was about control, that the colonial government should imbue a more direct management system of the country's resources. See Munro (2009).
The reference to 'van Steenis' is to C.G.G.J. van Steenis (1901-1986), at that time plant taxonomist of the Herbarium at Buitenzorg.
In his oration to commemorate the 136th anniversary of the Buitenzorg Botanical Gardens (Baas Becking, 1947c), Baas Becking remarked:

> Now clear cutting may cause erosion. And not only clear cutting, but also the abandonment of the arable land. When the sucking force of the towns in the United States became too strong by events not to be foreseen of the so called economic society and the arable land was abandoned, desert formation, the dissipation which we will call Diaspora set in on a large scale. Not for nothing archaeologists rush to the deserts, because these are the interred towns, the former trophegaia of Turkestan, Mesopotamia, the Gobi, the glory of what once was Greece and, Rome, the Holy Land. Our footmark is the desert. A policy which in the progress of the conversion from Eugaia to Trophegaia, takes into account the possibility of formation of this Diaspora, in other words a policy which considers the dynamic equilibrium between mankind, soil and plant cover, this Is what is called conservation, but which perhaps should better be named integration.

In the 1953 version of *Geobiology* Baas Becking remarked: (p. 573):

> With the absence of vegetation, we enter into "pure" geology. It is interesting to note that the karst landscape in Istria has developed only after extensive, and rather recent, deforestation. Another classical karst region, the plateau of the Causses, the region of the Tarn River, in the Central Massive of France, has been a classical region of intensive 'wood butchery.' In these regions the limestone is disappearing at a rapid rate, partly in underground rivers. This soil was preserved for millennia under the efficient cover of a beautiful oak forest.

See also Baas Becking's open letter to Samkalden about deforestation at Java in *De Groene Amsterdammer* (Baas Becking, 1947d).

8.1.7 Overgrazing, overfarming

(*The Rape of the Earth*, *Mankind at the Crosswoods*, East, Lowdermilk).[4]

8.2 Taboos

(*Homo ludens*, J. Huizinga).[5]

8.2.1 Introduction

Man is, like certain birds, a player of games. The greatest game is "make believe." If reality hurts, let us play that game. Let us plan that we, in our paper tent, are safe from the storm. Let us embellish this tent with pictures. Do not look out, that is against the rules. One might see the dark storm cloud. They are not there. We are safe inside our little tent. There is a picture in it of Santa Claus and J.P. Morgan.[6] Let us see what science brings in. All marvellous toys but too difficult for us to understand, but beautiful toys to play with. We only know that we want plenty of glittering toys to play with. What they do and how they are made? It does not interest us much, we only know that we are infinitely important, that the earth is our apple, that science is our toy and that we are jolly well capable of destroying the whole earth. We are little tin heroes.

8.2.2 The paper world and its properties[7]

In the paper world natural law is made not by act of parliament. These laws form a closed entity, without much disharmony, as a mathematical system they would be, therefore, acceptable. Unfortunately, they show very little semblance to reality. In the paper world people have no mother. It is an animalcule's world like Leeuwenhoek's or Aristotle's.[8] In the paper world people sit forever in committee meetings, settling dividends or laws or treatises or codicils or wills or affidavits, for there is nothing but paper. The paper world is an invention of the city. Wheat is not *Tritium vulgare*, a wonderful thing growing on a rich field. It means shares, posts, bulls, bears, brokers, tape ticking men, tape rooms of paper. Paper itself is no more a thing that came from a forest or a fibre plant, it may be shares or reports or papers. It is the essence of the large make believe masquerade into which Man has thrown itself going from paper to paper with paper communicating on paper about paper.

Having caged himself in, built himself in brick walls, concrete and iron and glass, man has shut himself out from the earth. Now there are certain individuals happy in such an atmosphere. They are urban, they believe in the paper world, the reality being, to them, a nasty necessity. As long as others exploit the world in a way, which increases their Babel, they leave the earth alone. They have cut themselves off from nature, not from ignorance, but by choice. No sentimental Rousseau, no healthy outdoor person, could persuade them that man is essentially an inhabitant of glass and brick cages, overheated. That nourishment, amusement, pursuit in general should have as little as possible to do with the natural world. They play make believe with their papers. They make Kings and Presidents and Ministers and Councillors, while the farmer ploughs. They, like the Athenians, rave on market places, while the Boeotiers harvest the wheat.[9] And in their boundless ignorance of natural conditions, they incorporate the others in their game, and order them (and the earth) about and – to perdition.

8.2.3 The exalted position of mankind

Genesis 1:26 Be fruitful, and multiply, and replenish the earth and subdue it.

4 Jacks and Whyte (1939), *The Rape of the Earth. A World Survey of Soil Erosion*. On p. 249 Jacks and Whyte, experts in soil sciences and pastures suggested about soil degradation in Africa that "white man's burden in the future will be to come to terms with the soil and plant world, and for many reasons it promises to be a heavier burden than coming to terms with the natives."
East (1923), *Mankind at the Crossroads*. Edward Murray East (1879-1938), American geneticist, botanist, strong supporter of the eugenics movement in the USA. *In Mankind at the Crossroad*, he compared groups of people based upon racial categorisations of the time.
Walter C. Lowdermilk (1888-1974), forester and hydrologist. In June 1939 he made a speech on Jerusalem radio entitled "The Eleventh Commandment." According to Nash:

> He reasoned that if God could have foreseen the ravages that centuries of thoughtless forestry and agriculture would bring to his creation, he would have been moved to add to the Ten Commandments. The eleventh, according to Lowdermilk, would "complete the trinity of man's responsibilities – to his Creator, to his fellow men, and to Mother Earth." […] Lowdermilk succeeded in making conservation a moral matter.

Nash (1989), *The Rights of Nature: A History of Environmental Ethics*.

5 Baas Becking referred to the Huizinga (1938) [A Study of the Play Element of Culture]. In the Section *Man and Man* in the 1953 version of *Geobiology*, Baas Becking (1953a) remarked (p. 703-704):

> This symbiosis is the subject of the science of sociology. Only the sexes show somatic differences, while in the social insects we recognise, also structurally differentiated workers and soldiers. To analyse the various forms of human symbiosis would fall outside the scope of this essay. One thing, however, is of importance to us here. Apart from sexual differences, the potentialities of an individual man are almost equivalent to the potentialities of mankind. When we do not carry this statement to extreme (where it most certainly would lose its validity) we might say that any man may function as "homo ludens", "homo faber" as well as "homo cogens." This fact gives us great hopes. Artificial environment may specialise men to a great degree, yet their offspring will be able to carry out all human functions. This elasticity of man, this storehouse of an untold number of potentialities must have saved the species from extinction several times.

6 John Pierpont Morgan (1837-1913) American banker.

7 In the 1953 manuscript of *Geobiology*, Baas Becking remarked under the heading *The Idols of the Theatre* (p. 795):

> Les hommes ont créé une planète nouvelle:
> la planète de la misère et du malheur des corps.
> Ils ont déserté la terre…
> Ils ont des morceaux de papier qu'ils appellent argent.
> Jean Giono. *Les vrais Richesses*.

In the "paper world" we meet with a powerful group of officials who seem to have created a complicated world of make believe. While borrowing elements of reality to regulate human intercourse their measures are often remote from reality. Natural law and Human law shall remain strangers to one another as long as the directives and motives for the latter are not based upon the former.
[…]
To those who like to do things it often seems that we are governed by those that have but little contact with reality. But the doers of things forget in their impatience that the rulers are governed also by formidable Idola Theatri of which the most formidable is the paper world. Against this copy world (a world of desks and telephones and stacks of print or typescript and, fortunately, waste baskets) we stand helpless. For whenever one wants to perform, they start to throw with paper. Like termite larvae, they subsist upon it and expect us to join in their enthusiasm most good deeds are choked in paper. The God given energy, the God given products seem merely phantoms to this world.

> L'immense terreur collective ébranle la société;
> nos morceaux de papier, nos morceaux de papier:
> gouvernements, ministres, députes, rois,
> empereurs, lois, lois, lois humaines au secours!
> Jean Giono.

8 Baas Becking referred to Anthonie van Leeuwenhoeck's 'animacule'.

9 Reference to Baas Becking (1928a). See also van Berkel (1996, p.183-187).

This is the first reason why the paper world was invented. Man should be at the head of the procession. Maybe the inferiority feeling due to our more than ugly exterior needed compensation, and we have found this compensation in exalting ourselves, nobody else being present to exalt us. Now it must be granted that *Homo sapiens*, and especially *Homo ludens*, have a great many remarkable qualities. That even there is no doubt that in most things he far transgresses anything else in creation. But to use the judge's mantle for the entire earth; are we up to this? Do we really want to be steward of the earth? We owe it nothing, it has been given to us, we are capable to destroy it, let us try it, just for fun. For life down below is a delusion anyway, let us contribute our shame to vandalise this earth a little further, for, not only that we are the best thing on earth. The earth is a centre of the universe, and we are monsters of the earth. Consequently, we are grand exalted "masters of the universe." Poor grand exalted monsters; ridden by disease, ridden by their passion and by their hormones. Yes, we know, because we sinned in the beginning, we are this dualistic thing! It is so easy to satisfy our maniac depressive nature; today the great master of galaxy, tomorrow the miserable worm! The truth is that if we only wanted to, we could make our scurvy pack into a small group of almost angelic beings – men like God – if we only had the courage. If we only had the courage, we could make the earth into one wonderful garden – if we had the belief and the courage, we could use the efforts of every individual towards these ends. We slap ourselves on the back when we have created another desert, increased the humble Babel which is this world.

8.2.4 The precious nature of man

What is the value of man? If we think as human beings, we have a predilection for man and we think that more people would be more fun and we say; "the value of man is infinite."

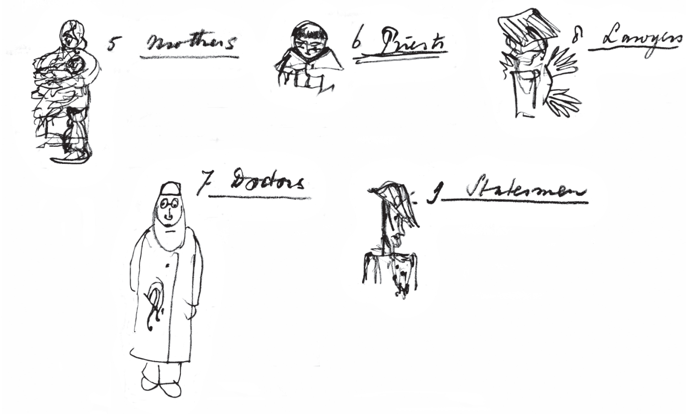


Figure 8.1 Five vignettes (circa 3 × 3 cm) in the margin of paragraphs; Mothers, Priests, Lawyers, Doctors and Statesmen.

8.2.5 Mothers

Mothers have, apart from their rational maternity, a hormonal dictator within themselves, a great propagandist for (quantitative) mankind. "Human" is the highest epithet and this means usually "more human protoplasm." Therefore, with mothers one mustn't talk, only sympathise.

[Vignette of mother and child, see Fig. 8.1.]

8.2.6 Priests

For him the value of man is revealed. Revelation is a thing one cannot talk about. With priests, therefore, one shouldn't talk, only pray. But still, they influence the world, chiefly in a negative way. They oppose. If our conclusion would be to take a certain sociological measure, in order to secure mankind for a few generations to come, we know that, whatever this measure, the priests would oppose us. For in that what is revealed there is but little subject matter, and most of this subject matter is not concerned with the awful problem which faces us now. The problems of a sparse population in a wide world are slightly different from a semi-dissipated earth half choked in human blood and in humane protoplasm. This era does not concern the priest. It is all very beautifully said by Christian Morgenstern.

[Vignette of priest, see Fig. 8.1.]

Ein Hecht, vom heiligen Antōn bekehrt,
beschloß, samt Weib und Kind,
am vegetarischen Gedanken Moralisch sich empor
zu ranken.

Drum frass er nur seit dies:
Seegras, Seerose und Seegrieß.

Der ganze Teich ward angesteckt.
Fünftausend Fische sind verreckt.
Doch heilige Antōn, gerufen eilig,
sagte nur: Heilig! heilig! heilig![10]

I do not believe that churches have enough potentialities to meet the conditions of today. They have been singularly silent in the great social and industrial evolution; they have been almost silent against war; they shall be silent in any other new calamity that shall visit the earth. Up till now the greatest was the economic theory of living, and the church has cooperated heartily with those that enthusiastically upheld this vulture and hyena theory of mankind. For you can have it just as you want it for, like Janus. Biblical Man has two faces, speaks with two tongues, blows hot and cold simultaneously. A church which not only hopes for a better world hereafter but actively builds for a better world today, would be an unheard off innovation. And still, I cannot but help to think that God only helps those that try to help themselves and others.

10 Christian Morgenstern (1871-1914) Der Hecht [Northern pike]. Baas Becking's version lacks lines 7 and 8 from the original. Also, the number of fishes (5,000) differs from the original version ("fünfhundert"). Lines 7 and 8 in the Morgenstern original read: "Seegras, Seerose und Seegrieß/ Doch Grieß, Gras, Rose floß, o Graus."
A pike, converted by St. Anthony decided,
together with his wife and child,
to become vegetarian and climb himself the moral ladder.
Therefore, he only ate since then, Seaweed, water lily and sea grits.
The whole pond was infected. Five hundred fish perished. St. Antony, summoned in haste, only said: Holy! Holy! Holy!

8.2.7 Doctors[11]

[Vignette of doctor, see Fig. 8.1.]

8.2.8 Lawyers

They are the mothers of the papers.

[Vignette of lawyer, see Fig. 8.1.]

8.2.9 Statesmen[12]

They are the priests of the paper world.

[Vignette of statesman, see Fig. 8.1.]

8.3 Ceremonies

8.3.1 Introduction

[Baas Becking left this section blank.]

8.3.2 Exploration

"The cornucopia," the horn of plenty.

8.3.3 Exploitation

[Baas Becking left this section blank.]

8.3.4 Production

[Baas Becking left this section blank.]

8.3.5 Distribution

[Baas Becking left this section blank.]

8.3.6 Supply and demand

[Baas Becking left this section blank.]

8.3.7 Malthus again[13]

"Fortunately," (books on Economics say), Malthus was "wrong." Consider our wonderful world, in which supply even exceeds demand! And with an inexhaustible plenty, mother earth from her wrinkled crust supplies us, like the widow of Sarepta from her small course, unendingly.[14] Evil tidings there have been a plenty, of the ending of our oil, our coal. But these rumours notwithstanding here we are, ever increasing, ever demanding more and here is the earth, ever supplying. Surely Malthus must have been wrong.

11 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 28-30):

> The chief propagandists of the doctrine of the sanctity of the human protoplasm are the mothers, the priests and the doctors. One might add the politicians and the statesmen, but their motives are so mixed and so uncertain that we could easily win them over if they had a chance at a vaster Babel and mere oratory. The three first named categories are certainly noble in their purpose. Their purpose, however, while seemingly constructive and beautiful lead, in reality, to disaster. Amongst the three I shall only speak of doctors. With mothers we cannot speak, only sympathise, with priests we cannot speak, only pray. Like my friend van der Hoog has said, the symbols of the doctor are the caduceus and the stethoscope, a strange blend of witchcraft and science. In their mind there is an equal mixture of natural law and lawyer's nature. They straddle the gap between science and the human sciences. Sometimes they fuel between these two chains, sometimes they claim to ride both horses at once, in most cases they start in science and end up in social science, but social science of a rather emotional and uneasy brand. Afraid to insult (for there is also the daily bread) afraid to injure (because they are trained to heal) incompetent to do the obvious (because legal power is contrary or lacking) they cover their actions with a veneer of secrecy. Vested with an enormous potential social power they do very little except stabilise the present structure. They refuse to accept the applicability of biological law in its broadest sense, about the issues of sterilisation, pre-marriage examination, and eugenics in general, and also about euthanasia, all subjects the value of which is plain and obvious to any mind not stuffed with fairy tales, they hear, they hem and saw. They comment (rightly) many of the ensuring measures with most undesirable forms of government, and because of this connection they refute the validity of the issues. There is a possibility, however, in the medical men. Most of them, when not too old, are sufficiently interested in science to see the validity of scientific argument. Emotionalism, which sways them to such an extent later, has not taken that deep root in their mind.

Manuscript *The Kingdom of this World*, Leiden University Library BPL 3233.

12 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 25-27):

> Only by probing into foibles, only by looking at ourselves as so many patients, may we ever hope to be worthy of a rejuvenated earth. For man's hope does not lie in his instincts but in his plasticity which, grinded by the intelligence, offers almost boundless possibilities.
>
> Possibilities destructive and constructive, of evil and of good, easily swayed, greedy, afraid and superstitious. It shall need steady hands to steer the course. Is there, as yet, a course to steer? I believe that there are pilots to steer this course, man of great experience who have exploited every creek and watercourse, who have charted the beaches and marked the tides, who know the direction of prevailing wind, the signs of changing weather. These pilots have never been allowed aboard. The ship has never been steered by navigators but by lawyers, schoolmasters and parsons. Trained orators but, like King Carnut, unable to impress the ocean by their vocal constructions. Or, in plain language, the forces constructive and destructive are physical and biological forces. The people who devoted their lives to the study of these forces, physicists, chemists and biologists are not allowed to take social responsibility over their own brainchildren.
>
> The foster fathers of the scientist's brainchildren are the wordmongers, the demagogues, in one word the Statesman. We shall have occasion to revert to this problem later in this essay. Surely, the scientists themselves are not without guilt. They have stood off and sneered, while grammar school teachers tried their hand at engineering, bankers ventured into applied biology and corporation lawyers presided a meeting on industrial chemistry. Surely, we are a plastic species, but even if the specialisation in our symbiontic socium is not hereditary, specialists should be used in their specialty. If a person is only fit to produce carbon dioxide, let him do so, but do not ask him to lead nine million people to destruction.

Reference to Carnut, 'Prince of the North', in Jacques Henri Bernadin de Saint Pierre's Études de la Nature (Studies of Nature).

Manuscript *The Kingdom of this World*, Leiden University Library BPL 3233.

13 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking did not give an ironical impression of his opinion of economics (p. 1 and 2):

> The war has for me as a living being, only one issue (the other being death). The thing I am most curious about is whether the *Homo economicus* has survived. If he has, all that I shall dream about in this essay, will come to naught, for I want to dream about the *Homo felix*, the happy man. Economic systems certainly did not primarily aim at happiness, they seem in the majority of cases, even inimical to it. But why live, if there is no happiness? Many religious systems have adroitly dodged this question. They postpone the happiness to the hereafter. The Kingdom is not of this world, not of this earth. After the hopeless mess people make of their lives (and of their neighbour's lives) they may hope for a harmony after they leave the arena of their incompetence.

On p. 42 to 50 he further specified his personal opinions on 'Economic theory:'

> "Economic motive", is the foundation stone of theoretical economics. The concept implies "the least sacrifice to reach a given end." In this, economists assert, there is no egotistical element, no one could object, they say, to a rational proceeding. And it is rational to follow the line of "maximum gain", of "minimum sacrifice." Economic progress goes parallel with the wider application of this economic motive. Economics is the (causal) science of prosperity. By prosperity is meant purchasing power. A liver on a platter is (apart from culinary associations) a ridiculous object. The liver within the organism is a most wonderful piece of architecture. One might therefore, object, that the few definitions quoted above, sound ridiculous (as they sound ridiculous to me), because they segregate topics from their organic nexus, topics which may only be understood in the correlative. For nothing to me, seems more irrational, as to measure prosperity by purchasing power or gains. That this is actually meant follows from the definition of the "economic organisation." This body originates from the cooperation of the entrepreneurs directed towards the obtaining of commerce profit.
>
> Wherever we sound economic theory, we find similar definitions. Therefore, the assumption seems not illogical, that gain, profit and purchasing power lie at the base of economics and that these concepts are axiomatic and, to economists at least, self evident. I grant that economic theory, without subjective, ethical implications, is possible. It is, however, purely a paper structure. It seems impossible to me to separate economics from the socium. 'The rules of the house' are nothing but economics. The pertinent question may therefore be raised, whether "economic motive" comes natural to mankind and whether the man "that goes out to buy cheap and sell dear" (*vide* economic motive), is a true representative of his species.

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14 For 'Sarepta' see 1 *Kings* 17.

8.3.8 The socium[15]

Should be a "stationary state", a "harmony", a "harmonic equipotential system" (Section 4.1.5.f).

But they rather say "carpe diem, quam minimum credula postero."[16]

8.4 Tropho, Oiko, Kinogea[17]

8.4.1 Introduction

Jean Brunhes, 1926, "Politique est un mot dérivé de qui signifie [Greek] *oiko,* la ville, la cité, la cité état." Pages 1-10 very interesting city plans! In particular for pages 8-9.[18]

8.4.2 Trophon

Is what not only going from the hand to the mouth, it is also that what we have to wait for before we may eat. It is also that, which supplies our immediate deficiency. The lack of pelt creates the want of clothing for example.

Brunhes (1926, p. 137-139, p. 143), Kino, "Qui aime la ville construit la route."

8.4.3 Forests

When man came of age, woodlands covered most of the earth. Woodland, from which man came, a world full of promise as well as of horrors. It seems trivial to reiterate the series hunter-herdsman-peasant, but we think of the hunter as primarily belonging to the biocoenosis of the forest. Ruminants made the grassy clearings and formed the hunter as a herdsman. The ruminants became the slaves of man. And man lived in

15 'Socium' is a term of Baas Becking roughly meaning 'human coexistence' or 'community'.
In his unfinished essay *The Kingdom of this World* (1942-1943, p. 22), Baas Becking remarked:

> The natural unit of human symbiosis is the family. The instinctive social feeling usually does not transgress this socium. However, in the higher communal units intellect makes up for the lack of instinct, resulting in a society with quasi-vital properties. Here we find coordination of organs, specialisation, exchange, in short, a complete metabolism. In the social insects, family and state merge into one another. Here the specialisation within the socium sometimes finds its expression in a polymorphism. We find queens, workers, soldiers. Not always this specialisation is genetically fixed, in many cases the nature of the nutrition determines appearance and function of the individual.

On p. 44 and 45 he wrote:

> The individual is in constant interchange with its social environment. This interchange consists of both centripetal and centrifugal elements. A centrifugal ("egofugal") element is self assertion, to live as many lives as possible in the three score and ten years allotted to us. Centripedal ("egopetal") elements are "greed and breed," "Hunger und Liebe", the latter being Eros rather than Caritas. Caritas is a centrifugal social factor. Greed, breed and self assertion are animal rather than human functions, still "economic decline seems to be based upon them. The "healthy, normal child" shows a strong sense of possession; "This is mine, that thing is not yours," "give it to me," "I want to have it." These are, honest and firm assertions, belonging to a young animal that wants to maintain itself in a (fragmentarily understood) environment. In secondary school the number of children that show this propensity is already considerably diminished. We all know of the one boy in our grade who sells toys, toffees, stamps or butterflies. When we pass puberty the normal sense of possession is further weakened. Perhaps it goes with the atrophy of the thymus gland. We know, from our war experience that almost everybody is not really interested in possessions, we have been driven out of house and home too often, we know of other things more important.
>
> But still, there are people in which the economic motive, as an infantile, a neotenic [= juvenilisation] character, persists throughout this mental life. Do they suffer from endocrine disturbance? There are reasons to believe that those people are abnormal. Their suggestive power, however, is very great. They promote babel in general, envy, politics and war, because it serves their ends. Because they collect money, they can hire and fire, purchase and enslave to their heart's content. Their propaganda we shall meet everywhere in this essay, for they are the great vandals and, although individually often very likeable fellows, powers of evil in nearly every aspect.

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16 Latin aphorism, usually translated "seize the day", from Book 1 of the Roman poet Horace's work Odes (23 BC).

17 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 38-40):

> Before we analyze these various relations of Man and Earth it is well to classify them provisory, while, of course, every system condemns itself, and for any form of thought-matter there are many systems of classification possible. In this essay a practical system will be followed which is, unfortunately, not entirely homogeneous. Partly it is based upon our primary needs for food, clothing, housing and communication. Partly it refers to the forms of mutilation with the earth underwent by our effort. What is left after all these relations have been dealt with, I shall call the "*Engea*," the real earth, that once was (a thing to dream about). We collect our food, in the widest sense of the word, from the forest, the field, the river and lake, from the mines, from the ocean. This I shall call the *Trophogea*. It represents a great variety of relations, some are self-perpetuating, some lead to irreversible situations. Most of the mere structures that are anthropogenic and revert to other forms of earth after shorter or longer period of disuse.
>
> It is hard to say whether the hoarding places of the trophon, such as warehouses, silo's and haystacks should be classified under the *Trophogea* or under the next primary form of earth: the *Oikogea*, where we have our home. This home may be a house or a palace, a hamlet or a town. They almost invariably belong to the dysgenic factors in relation to the earth. It will be shown that the towns nearest relative is the desert. This lenticular organis, sucking dry its surroundings, is in itself arid and forbidding. The oikogea itself is inter-penetrated by the 'traffic earth,' the *Kinogea* which comprises streets, alleys, roads, highways and sea lanes and the traffic carriers upon them. This is the Kopcogea where the excretions, the excrement of humanity, accumulates. The sludge heaps, the garbage, the refuse and offal, *Kopcogea* is increasing.
>
> There is *Kakogea*, the wasted earth, the deserts, mainly anthropogenic, that are Man's own trail, the hopeless sign-boards along our roads also belonging to *Kakogea*. Our efforts at beautification have created *Kalogea*, there are our gardens and our parks, subconscious microcosmic efforts to imitate the Archegea, the earth as we believe it to have been before we oversaw it. Machegea, the war earth is a special form of *Kakogea*, inasmuch as war has its own particular excretion-products into the milieu externe. Finally, there is Engea, the 'Good Earth,' a thing to dream about. This is the, a park-like thing in which Man lives in harmony, and not at odds with the rest of creation.
>
> Now, inasmuch as communism in a way, is an inverted capitalism and therefore takes cognisance of this phenomenon for more than its worth, the above classification is related to economic theory, inasmuch as it takes into account the so-called "primary human wants," trophon and oikos. It takes into account, in the *Kinogea*, the problem of distribution. But instead of leaving the problem in the factory, in the office, in the stock exchange, it is here projected upon the earth, its influence upon our planet is traced. Economic system in itself being chaos, it cannot create but chaos, and that is actually what we reap now.
>
> Before examining our relations to the earth in detail, we have to consider briefly what economics has contributed towards our problem. It describes the "official", the 'High-Church' attitude of Man towards the earth, the attitude of the businessman and the 'inverted business man' (nevertheless still the same in its make up); the worker. They all draw upon the terrestrial capital. Therefore, we also should consider this terrestrial capital in detail. To use an obvious word, "the natural resources," the implication being that it is all ours to devour, to mangle, to spoil and devastate.

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18 Jean Brunhes (1869-1930). French geographer. Baas Becking referred to the third edition that was published in two volumes in 1925. His references however, cannot be traced in the *Geographie humaine*. In *La Géographie humaine* (Brunhes, 1925) he classified the 'essential facts' of human geography into three main groups:

1. Facts of unproductive occupation: houses and roads.
2. Facts of plant and animal conquest: cultivation of plants and raising of animals.
3. Facts of destructive exploitation: plant and animal devastation; mineral exploitation.

Brunhes explained man not as completely dependent on geography. He saw in nature "not a tyrannical fatalism, but an infinite wealth of possibilities among which man has the power to choose" (S. Charléty, 1932), *Notes sur la vie et de traveaux de M.J. Brunhes*. Paris).
In his 1953 version of *Geobiology*, Baas Becking described Brunhes's approach in a section *The Exploitation of the Earth* (p. 775-776):

> Our manifold activities leave their imprint upon the landscape. This imprint may be in the nature of a proud hallmark, it may be a tool mark, but often it appears as a wound, a scar or a skin disease. It may be useful to classify these influences. The method of approach followed is inspired by Jean Brunhes (1926). There is the unexploited earth which we call *Eugaia* (the food). When Man arrives, he exploits the range and fells the forest. Oil is struck in the prairie, copper is mined. To satisfy his wants, he creates *Trophogaia*. He makes a dwelling place, in the farm, the village and in the city and we meet with *Oikogaia* (the dwelling) From dwelling to dwelling, from town to town, we travel and develop highways, railroads, aerodromes, harbours, to further our communication. We create *Kinogaia* (I move). Thus far it may be for "better or worse." There may be town planning and landscape planning included as well as soil-conservation and rational exploitation.

the clearing and he decided that it was good to live with his cows and that the forest was still the place full of danger. And when agriculture came upon man, apart from the need for grass, there arose a need for more soil, more clearings. And with fire and with axe he began to attack the wood, also to build his huts and stalls and granaries. And this semi-immaculate sense towards forests, which were vegetation climax and from which emanated all we needed, persists up to our time when Jean Brunhes speaks of forests as things to be cut down. Well, maybe 3,000 years before the Christian era we started to cut down the protective covering forests in Turkestan, Afghanistan, Persia, and Mesopotamia. About 3,000 years later we started, with equal enthusiasm to pluck the covering from Northern and Western Europe, Greece. Italy and the Iberic peninsula having preceded us in this demolition rage. A beautiful pioneering life was led for a few generations anyhow.

8.4.4 Meadows

Holland is holtland means woodland. There is no woodland now. Before the fourteenth century it was devastated, and only the local village names, like Hazerwoude, Berkenwoude *etc.* still witness, together with some subsoil material, the erstwhile luscious vegetation. [In the margin Baas Becking added: Scharwoude, Rijnsaterwoude, Hoogwoud, Berkel, Zoeterwoude.] If the clearing (a rode, Rhoden, Ruurlo, Rolduc) obtained a grass mat, its relation with cattle might develop into a stationary state – a meadow. Only in the last decades the scientific study of grassland is being developed (in our country by Dr. O. de Vries of the General Experimental Station at Groningen).[19] One thing is certain that steppe, pampas, prairies and other natural grassy-climax-vegetations are foreign to most parts of the world, and are only kept into being by cattle. As mentioned at another place in this treatise, a meadow, when left alone, will quickly revert to alder coppice, preliminary to a birch-oak mixed forest! In the same way heather without sheep does not persist, if, at least not burned or mown every year. Scotch pine will settle first, then climax being again birch and oak.

8.4.5 Field

[Baas Becking left this section blank.]

8.4.6 Agriculture and horticulture

[Baas Becking left this section blank.]

8.4.7 Plant products

[Baas Becking inserted Fig. 8.2.]

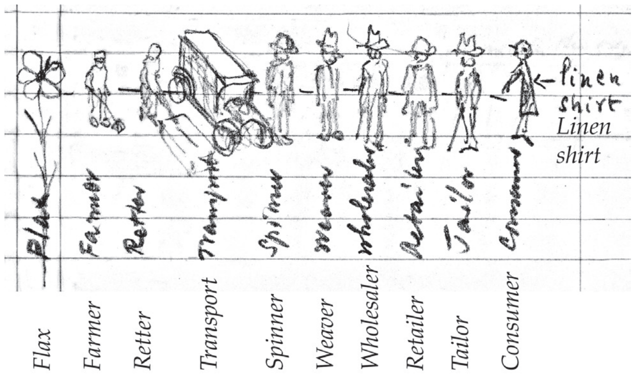


Figure 8.2 Sequence from flax to linen shirt.

8.4.8 Animal products

[Baas Becking inserted Fig. 8.3.]

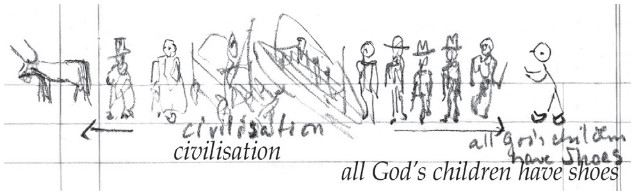


Figure 8.3 Civilisation process.

8.4.9 Mineral products

[Baas Becking inserted Fig. 8.4.]

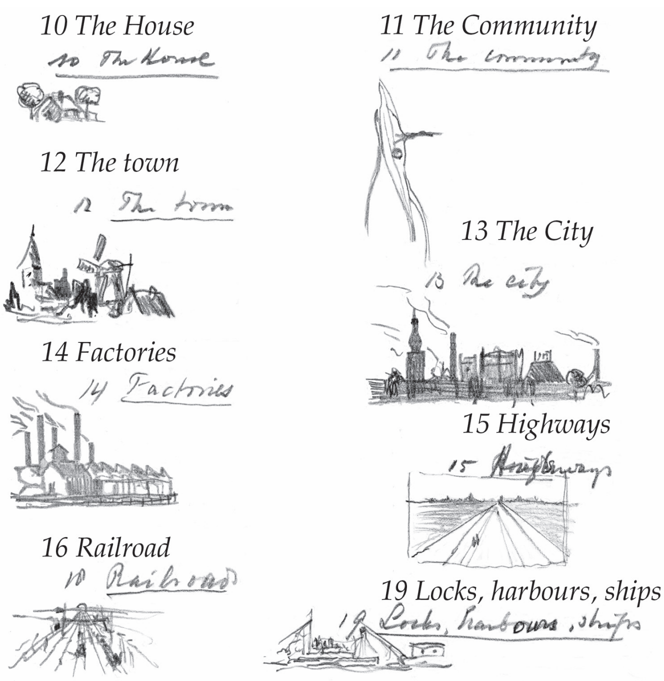


Figure 8.4 Eight vignettes (*circa* 3 × 3 cm) in the margin of paragraphs.

19 Professor dr. Otto de Vries (1881-1948), director Rijkslandbouwproefstation voor de Akker- en Weidebouw Haren (1930-1945). De Vries had been director of Centraal Rubberstation in Buitenzorg (1915-1930). De Vries was the son of the famous professor Hugo de Vries.

8.4.10 The house[20]

The conies have their holes, and many animals have forms of "cysts" to enclose them, when they need extra protection from external influences. The clothes supply a lack of pelt, a house a lack of communal cyst, like a spider cocoon.

[Vignette of house, see Fig. 8.4.]

8.4.11 The community

Companion with the organisation autosymbiosis and metabolism.

The animal cell with its nerves, veinlet and arteriole.

[Vignette of the community, see Fig. 8.4.]

8.4.12 The town[21]

There are still smiths and bakers and butchers. There are, in the immediate neighbourhood, semi-authentic farmers. This isn't bad. The paper world has not very much hold yet on this community. But there is loss of style and loss of much beauty and character every decade by the import of new goods, by creation of artificial demand, by the destruction of the old.

[Vignette of small town, church and mill, see Fig. 8.4.]

8.4.13 The city[22]

"Ich liebe die Städte nicht, dort gibt es zu Vielen von den Brünstigen" (Nietsche).[23]

"Les villes tentaculaires" (E. Verhaeren).[24]

"Politique est un mot dérivé de [Greek] *oikos* qui signifie la ville" (Jean Brunhes).

In a tissue culture a cell deprived of its specific organs, reverts to the type of the adhesive tissue, a shapeless characteristic sort of cell. Where specialisation becomes too far developed and too intricate it breeds shapelessness.

[Vignette of city, see Fig. 8.4.]

8.4.14 Factories

[Vignette of factory, see Fig. 8.4.]

8.4.15 Highways[25]

[Vignette of highways, see Fig. 8.4.]

20 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 78):

> In Urbo the house is reduced to a mere dwelling space. I know that suburbia (green grows my garden) hankers after a more complete existence. Their fulfilment again lies in a "micro-existence," like a Japanese garden, all on a soup plate. They have gardens, often with pools. They have garden houses, garages and other things even a badminton court. Just like their houses have real bathrooms, kitchenettes. If they ever visit a generous colonial or Georgian house, do they even feel, on their return home, a great urge to kick their fence through their garden house, and throw their bath tube in their fishpond?

Manuscript *The Kingdom of this World*, Leiden University Library BPL 3233.

21 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 77):

> I cannot share the enthusiasm of a Corbusier, of a Geddes for town planning. I cannot see the virtue of the sharing of pale and statistical joys with the millions. What I share with others is the feeling that I am an individual and that my blossoms, such as they are, are all of my own. The average man, if he existed, the healthy normal child, if it existed, would be an unspeakable horror. Why behave if we want to be such horrors? I cannot see any virtue in a modern city. I cannot see any merit in acres of small villas, where solitary beech trees still witness the former existence of a noble estate.

Manuscript *The Kingdom of this World*, Leiden University Library BPL 3233.
Baas Becking referred to Charles-Édouard Jeanneret-Gris (known as Le Corbusier) (1887-1965), Swiss-French architect and one of the pioneers of 'modern building', and to Patrick Geddes (1854-1932), Scottish biologist and pioneering town planner.

22 In his unfinished essay *The Kingdom of this World* (1942-1943), Baas Becking wrote (p. 79):

> Cities are "tentacular" [Eric Verhaeren has witnessed their enormous sucking power in his series of beautiful poems] "Les villes tentaculaires" [inserted by Baas Becking "Je suis un fils de cette race tenace dont les yeux plus que les dents sont voraces."]. Half urbane, he rings the praise of the city, he, who himself fell victim to its turmoil (he was overrun by a traincar).

Manuscript *The Kingdom of this World*, Leiden University Library BPL 3233.
In *Geobiology* (1953a), Baas Becking gave a further explication (p. 780-781):

> Brunhes (1926) describes the origin of small, local industries near forests, near deposits of pottery clay, or of surface coal. These products had to find a market. And the town, like the higher organism created a specialisation, a diversity, a division of labour which contrasts with the omnipotent single cell or with the small, rural, autarchic community. The biocoenosis of a town reminds us strongly of the autosymbiosis in a higher organism Cities have often a great centripetal tendency. The Belgian poet Emile Verhaaren speaks of "les villes tentaculaires." […]
>
> Cities such as these have drained the country. This drain, in many cases, has literally been a thirst for water, as is shown by large population centres, like Los Angeles, in semi-arid regions. There is also a thirst for produce and a thirst for men and this is the real function of the city. The city has parasitic tendencies. It is forever asking for more and usually it has little understanding, and less interest for the rural problems. It often shows dictatorial tendencies and Bruhes reminds us moreover that "politique est un mot, dérivé de oikos signifie la ville, la cite, la cite état." It is here that politics and political systems are made. Urbanisation, in most countries on the increase has profoundly changed the mentality of the community as a whole. For the city breeds a special, a more artificial type of mam and many are the changes that the rural immigrant has to undergo before he is completely urbanised. The urban has set the norm. it is in the cities that the artificial increase in wants has originated. The stony desert, the hamada, the senseless jumble of buildings, surrounding the city dweller has had a profound influence on his mentality. Condemned to be pressed in by numberless fellow creatures all day his sense of values must become warped. But we are actually in need of cultural centres, such as Universities, Libraries, Concert Halls, Art Galleries, Laboratories and Musea which should be the hearts of our cities.

23 Friedrich Nietzsche 'Von der Keuzheit' in *Also sprach Zarathustra* (1883):

> Ich liebe den Wald. In den Städten ist schlecht zu leben: da giebt es zu Viele der Brünstigen.

24 *Les Villes Tentaculaires* book with twenty poems written by Émile Verhaeren, published in 1895.

25 In his unfinished essay *The Kingdom of this World*, Baas Becking wrote about 'Kinogea, the traffic-earth' (p. 82-88):

> In diesem Dorfe steht das letzte Haus
> So einsam wie das letzte Haus der Welt.
> Die Strasze, die das kleine Dorf nicht hält,
> Geht einsam weiter in die Nacht hinaus.
> Das kleine Dorf ist nu rein Uebergang
> Zwischen zwei Weiten – ahnungsvoll und bang,
> Ein Weg langs Haüsern hin, statt eines Stegs.
> Und die das Dorf verlassen wander lang,
> Und viele sterben vielleicht unterwegs.
> [Rainer-Maria] Rilke [1901]

Rolling wheels, at first slabs of oak or joined planks, the heavy ox cart draws its tiresome way through the sodden or the dusty furrows, leading from stronghold to stronghold. Rolling wheels, with spokes and reins and lubricated axles of the diligence, the mail coach leading through mire and dust from church spire, to church spire, wheels of iron with heavy flanges, straddling the rails of the straight railroad track, leading from the station to the station. Rolling wheels, rubber rimmed of fast and last horse drawn vehicles, wheels, tyre rimmed, mastering the endless motor track that leads from nowhere to nowhere. With the wheel, the symbol of *Kinogaia*, we master distance.

The wheel is one of the few typically human tools. In living nature, we meet with almost everything that man has wrought later. The paper nautilus [= Argonaut, pelagic octopus with paper-this egg case that females secrete], the Portuguese man of war has sails, birds and insects have wings, but neither wing motion nor leg motion, so common in living nature, have been used by man. But we have used the wheel, the wheel that was never realised in living nature, because it implies protoplasmic continuity between cells, tissues and organs [that] no organism can persist. The propeller and the screw we find back in living forms, but never the wheel. Engines that run on legs we did not construct. Maybe in the future there will be engineers sufficiently versed in animal physiology, or physiologists, sufficiently versed in engineering, to realise this form of locomotion into technical sense.

8.4.16 Roads highways

"The stars are setting and the caravan starts for the dawn of nothing – oh make haste,"

Omar Khayyan.

8.4.17 Canals

[Baas Becking left this section blank.]

8.4.18 Railroad

[Vignette of railroad, see Fig. 8.4.]

8.4.19 Locks, harbours, ships

[Vignette of ship in harbour, see Fig. 8.4.]

8.4.20 Summary and conclusions

[Baas Becking left this section blank.]

8.5 Copro, Machega[26]

Brunhes (1926, p. 231).

8.5.1 Introduction

We have met man as creator, we saw him to his 'Shiva aspect,' as destroyer – changing crystal springs into reeking pools. Maybe the word express (excrement) is too good for the description of human waste, as the copros contains many ergones, capable of stimulating other life, human waste is usually toxic and barren.

8.5.2 Cyclic and dissipatory copros

[Baas Becking left this section blank.]

8.5.3 The household wastes

[Vignette of household waste, see Fig. 8.5.]

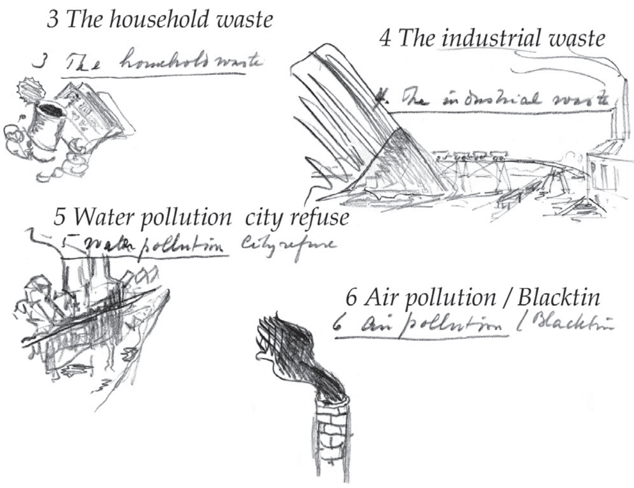


Figure 8.5 Four vignettes (*circa* 3 × 3 cm) in the margin of paragraphs.

8.5.4 The industrial wastes

[Vignette of industrial waste, see Fig. 8.5.]

8.5.5 Water pollution

City refuse. [Vignette of water pollution, see Fig. 8.5.]

Leo Minder in his treatise on the Zürichsee,[27] has shown that this lake has changed in the last decades, from an oligotrophic to an eutrophic body of water. It is not only waste, according to him, that causes pollution, *but also the completely mineralised effluent*, containing phosphate and nitrate, that causes the enormous water blooms of *Tabellaria fenestrata* (diatom) and *Oscillatoria rubescens*. Therefore, the usual procedure of sand filter and septic tank is not sufficient to ward off water calamities.

26 In the 1953 version of *Geobiology*, Baas Becking gave a vivid description of Koprogaia (p. 783-784):
In spite of education, vandalism is still rampant among mankind, and the amount of wanton destruction should not be underestimated. The transition between vandalism and motivated destruction is often rather vague. This is, in part the case in such procedures as fishing with dynamite, or certain forms of shooting, where the proud riflemen are photographed with an enormous "tableau." Destruction is often motivated by a satisfaction of a craving for power. It must be a glorious feeling to pull out many trees at once with one manipulation or to scrape an enormous gash out of a hill by means of a modern strip-mining bulldozer! War damage includes inundations, deforestation, demolition of buildings, trenching and the erection of many concrete structures, further the utilisation of houses, cropland, forest, and range in military preparations. The effect of military operations includes shelling, bombing and the total sterilisation of entire areas by atomic warfare. Western Europe, a battlefield for well-nigh two thousand years contains so much highly valued agricultural land that war wounds are quickly healed. Often an extraordinary effort has to be made to reclaim the war damaged area, chiefly when, after inundation with seawater, and the damage done to the dykes, the operation does not allow of delay, lest the land be lost. Cases in point are the Wieringermeerpolder and the Island of Walcheren, both in Holland, where a speedy effort saved vast tracts of land which was further improved by means of an artificial "metabiosis," starting with the salt tolerant rape seed, followed by barley and thus preparing the soil in but a few seasons for wheat, clover and grass. But not in all cases such a speedy rehabilitation may be effected. The sea and the land have to be swept for mines and ammunition dumps, huge concrete structures (meant to withstand heavy attack) have to be demolished, and bomb craters have to be filled and often whole cities have to be rebuilt.
"The earth is also defiled by the inhabitants thereof," *Isaiah* 24:5
Geopathology, suppose it were to be written, would devote much attention to the rocking pool (once a crystal spring), to the wholesale water and air pollution that seems an inevitable function of our modern civilisation. It would point to the mountainous slag heaps near our mines, and it would study the submarine refuse dumps, so well described by William Beebe. Man is a dirty feeder we have to thank the cellulose bacteria for the habitability of much-frequented landscapes, which otherwise would remain cluttered with our refuse. It is, strictly speaking, only the unutilised waste which is koprogaia for as soon as economic use is found for a waste product, it ceases to be a menace. At the other hand, while the value of many waste products is recognised, these products are often too much dissipated or too difficult to segregate to allow of rational use. And so, they remain to ell process where particles are separated in an electric field, has done much to improve the situation.

27 In the 1953 version of *Geobiology*, Baas Becking referred to Leo Minder on p. 785:
Even if no "objectionable matter" is present in the effluent, it may, by its mineral content, influence the biocoenosis, especially in closed basins. Leo Minder (1943) has called attention to the change of the Züricher See from an oligotrophic to a eutrophic community. The increasing knowledge of microbiology has done much to convert organic waste into useful products. In some starch and carboard factories, the objectionable waste is converted, by a biological process, into methane. Biological purification of water is often very efficient, but certain substances, like the sulphite waste of paper mills, are refractive to biological attack and remain a source of contamination. A peculiar aspect of the problem is shown by the waste oil in much frequented oceans, like the North Sea. This oil forms a sticky film over the feathers of birds, which prevents the birds from flying. In certain seasons there are literally hundreds of these doomed creatures to be found on the beaches.
Baas Becking referred to Minder (1943). *Der Zürichsee im Lichte der Seetypenlehre.*

8.5.6 Air pollution

(Blacktin (1934), “Dust”).[28]

[Vignette of factory pipe, see Fig. 8.5.]

8.5.7 Marine and submarine pollution

(W. Beebe).[29]

8.5.8 Soil pollution

[Baas Becking left this section blank.]

8.5.9 Fallowing[30]

[Baas Becking left this section blank.]

8.5.10 The origin of deserts

(Lowdermilk, *Deserts on the March*, *The Rape of the Earth*).[31]

Kansas

1. Mesopotania
2. Turkestan
3. Gobi
4. Sahara
5. Syria and Palestine
6. Trans Jordania
7. Thar
8. Arabia and Beluchistan
9. The red heart of Australia
10. Kalahari
11. American deserts, N. Mexico, Big Basin.

Wind erosion in Holland.

8.5.11 Erosion and Deforestation

What is more wonderful than arable soil, it is a witness of countless plant generations; of countless solar quanta being wed to ennoble the atmosphere, it is a witness of enormous chemical effort by a host of organisms, to produce this mellow, fragrant, dark, crumbly mass. Mother-of-plants, mother-of-men, topsoil. Below it the earth, although perhaps sedimentary, has not lived yet. This exciting cycle – it has not renewed itself in ceaseless giving in, ceaseless yielding, in continuous passage of the new which became old.

8.5.12 Reclamation

[Baas Becking left this section blank.]

8.5.13 Man as landscape architect

[Baas Becking left this section blank.]

8.5.14 Man as dissipating agent

In the concentration and wide dissipation of materials.

8.5.15 Man as negative selecting agent

It seems almost trivial.

8.6 Engea

Isaiah 60:13 The glory of Lebanon shall come unto thee.[32]

“Man’s happiness, that honey’d flower of soul, is his loving response in nature.”

Robert Bridge, *The Testament of Beauty*.[33]

8.6.1 Introduction

Bunker (1936, p. 344).

[Baas Becking inserted Fig. 8.6.]

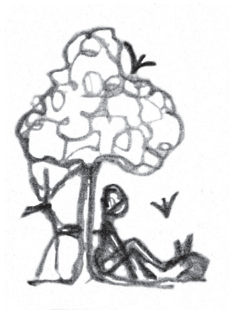


Figure 8.6 Vignette in margin (*circa* 3 × 3 cm) showing a person under a tree and a deer.

28 Reference to Samuel Cyril Blacktin (1934), *Dust*. According to a review of *Dust* in *Nature* (1935, 135, p. 894):
The author has considered every conceivable aspect of smokes and dusts, even explaining how they help in the scientific detection of crime. (Under the heading of ‘dusts’ he includes such widely diverse systems as sandstorms, volcanic eruptions and ice particles.)
A quote from this book: The dust hazards in flour milling, bakeries, bronzing or bronze manufacture, building trades, asbestos industries, and basic slag industries are probably better known. Thus, the asbestosis of the asbestos industries is now attracting much study, its effects being roughly analogous to silicosis, though it exhibits definite characteristics such as the ‘peculiar bodies,’ and the most dangerous operations are spinning and weaving. Fibrosis and tuberculosis often result.

29 Reference to Charles William Beebe (1877-1962), American naturalist, and marine biologist, well known by his deep dives with the Bathysphere off the coast of Nosuch Island in the 1930s.

30 In the 1953 version of *Geobiology*, Baas Becking specified his anguish about fallowing in the Dutch dunes (p. 788):
Deserts are, for a part, disturbed successions. We may witness the formation of desert, in a wind blown dune near the coast, but these dunes are only a phase in the succession of landscapes. But if the beautiful soil of the inner dunes, used for bulb culture, lies fallow too long, the wind will blow away the topsoil and new dunes may originate. The dunes at the sites of ancient villages in central Holland, which must have been there for many centuries have failed to regenerate into a continuous soil cover, in spite of the favourable climate. Several square miles of “blowing” dune may be the result of the amblings of a single horseman. A wound in the earth may be made in as short time, but it often takes centuries to heal, especially in semi-arid regions. Especially if the disturbance is repeated, great losses may be the result.

31 Reference to Paul Bigelow Sears (1891-1990), American ecologist and author of *Deserts on the March* (1935). Baas Becking also referred to Jacks and White (1939), *The Rape of the Earth* in Section 8.1.7.

32 Apparently, Baas Becking used the American Standard Version as source for his quote from *Isaiah* 60:13.

33 More exact the quote from Robert Bridge is:
“Man’s happiness, his flaunting, honeyed flower of soul
Is his loving response to the wealth of nature.”

8.6.2 Integration or conservation[34]

[Baas Becking inserted Fig. 8.7.][35]

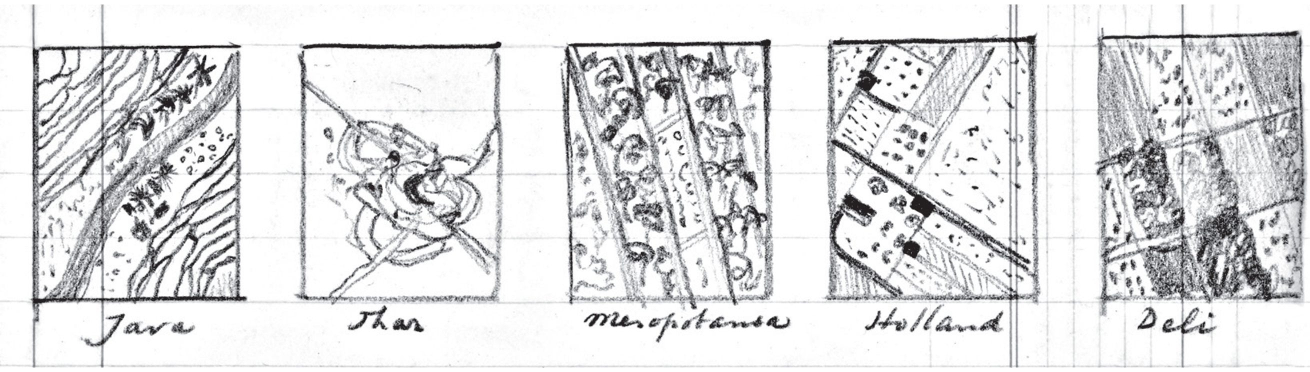


Figure 8.7 Five small drawings of landscapes in Java, Thar, Mesopotamia, Holland and Deli.

8.6.3 The soil

[Baas Becking left this section blank.]

8.6.4 The plants

[Small drawing of a tree.]

8.6.5 The animals

[Baas Becking left this section blank.]

8.6.6 Man[36]

[Baas Becking left this section blank.]

8.6.7 Interrelation of soil, plant and man

[Baas Becking left this section blank.]

8.7 Dissipation[37]

8.7.1 Introduction

Isaiah 7:11 "Then I said, Lord, how long? And then he answered: until the cities be wanted without inhabitants, and houses without man, and the land be utterly desolate."[38]

8.7.2 Procedures in agriculture

[Baas Becking inserted Fig. 8.8.][39]

34 In July 1945 Baas Becking contributed a short essay [*The Dutch Indies a Poor Country?*] to the periodical De Opdracht, in which he described the potential productivity of the "half explored, hardly exploited enormous land. […] We want to see the population of that land happy. We shall succeed in that. We shall revive the latent resources into living richness." In August 1945 he wrote in De Opdracht an essay [*Three Phases in the Approach of Agricultural Problems*], in which he referred to his discussion with the Government of the Dutch Indies in 1939 about the traditional system of rice culture, which he characterised as "the classical example of an integrative culture in which a dynamic equilibrium is maintained between soil, plants and man." He proposed a "rational exploitation instead of a plan-economical" approach:

> The luxuriant man, the opulent man is the greatest parasite the earth has ever known. And with the destruction of the earth the welfare of this man can increase temporarily. However, this welfare bears in itself the germ of destruction. Not the economic problem as such, not the agricultural or hygienical questions must be placed in the centre, but from all these problems one integrated whole must be constructed.

See Baas Becking (1945a and 1945b).
According to Baas Becking this "integrated approach adds one factor to the existing building, tightness and sustainability."

35 The five small drawings in the Geobiology manuscript were described by Baas Becking in *De Opdracht* (Baas Becking, 1945b):

> Java, the land of contour terrasses, where the soil is held as much as possible, stands in a stark contrast to the tin and rubber deserts of Malacca; both operations have contributed to major land destruction. Burma is still in pristine condition, but between Calcutta and Allahabad one gradually enters the dry area, finally flying over the great Thar Desert in the Allahabad-Jodphore-Karachi region. It is extremely curious to see from the air that the typical "agricultural grid" of the British Indian village in this desert is still visible from the air. One can still see the foundations of many villages, over which the drift dunes have passed. In Arabia and Afghanistan, the construction jar has long since been washed into the sea. These countries seem irreversibly devastated.
>
> Between Baghdad and Lydda across the Trans-Jordanian desert, the ancient Assyrian, straightforward farming pattern is seen on the whole road. Sometimes as many as three systems above each other and the harsh sandy plain is the silent witness to our violation of the earth. The route to Alexandria, the route from Athens to Naples is equally desolate. Where Menelaos's nephew Telemachos proudly showed his large horse pastures and farms, where the shepherds sat down in the pawnshop, is now a decomposed and dethawed landscape. And finally, one sees Italy's harsh de-fleshed spine: the Appenines.

36 In the 1953 manuscript of *Geobiology* under the heading *Chief Contributions of Organisms to the Earth*, Baas Becking remarked (p. 155-156):

> The pivotal position of Man in the Universe, sadly shaken by Newton and the subsequent development of celestial mechanics (Laplace) was further attacked by evolution. Undue emphasis was therefore placed on the anthropogenesis, the descent of man as a logical consequence of evolutionary thought. And up to this day it has remained a dangerous business to talk about Man, particularly in his 'Caliban' aspects. The ire of Caliban is easily roused. According to Oscar Wilde, Caliban is equally enraged when he sees his face in the glass or when he fails to see his face in the glass And Victorian industrial progress, inevitably leading to an exaggerated confidence in our prowess could ill support such an uncertain pedigree for such an exalted being. Even without Man raising his ugly face, organic evolution still remains as a great cultural contribution, the portent of which we cannot, as yet (a century later), evaluate properly. And while the theories of evolution may be stained by pride and prejudice, there are certain fundamental facts that remain.

37 See Baas Becking (1942a); Baas Becking (1946b), in which the fourth section deals with 'Dissipation'. See for 'dissipation' also Section 6.1.1.

38 Baas Becking quotes *Isaiah* 6:11, from the New American standard version.

39 Description taken from *Geobiology* (1953a).

> The farmer has in his possession, the seed grain, a high concentration of organic material. This he scatters over the field. The seed germinated, even before its endosperm is exhausted, it starts to accumulate carbon from the air and minerals from the soil, and water from both. In the growth process, it accumulates not only tenfold in grain, but also the chaff, the straw and the stubble. It has been actively fighting dissipation, such wheat plant has become a veritable centre of accumulation. This concentration further increases during harvest and finally, after threshing, there is again a concentrated mass of organic matter. This matter is dissipated in various ways before it is consumed, the seed grain excepted. A number of organisms pray on it, and during milling and processing, during distribution and storage, there is loss. Only part of it is recovered into human protoplasm and into human energy. Some of it is temporally immobilised in objects less perishable, such as fibres and plastics, cardboard and other articles. In these products the wear and tear will also increase dissipation, but at a much slower rate.

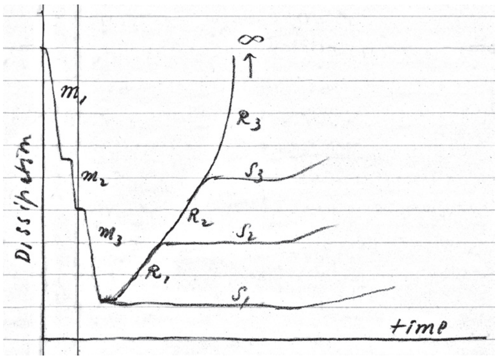


Figure 8.8 Relationship between dissipation of carbon and time in growing and processing of wheat: m1 sowing, m2 growing, m3 ripening, harvesting, threshing, R1 distribution, R2 baking, R3 consuming. S1, S2 and S3 storage at the three levels.

Soil dissipation. Soil theft (Boskoop).[40]

[Baas Becking inserted Fig. 8.9.]

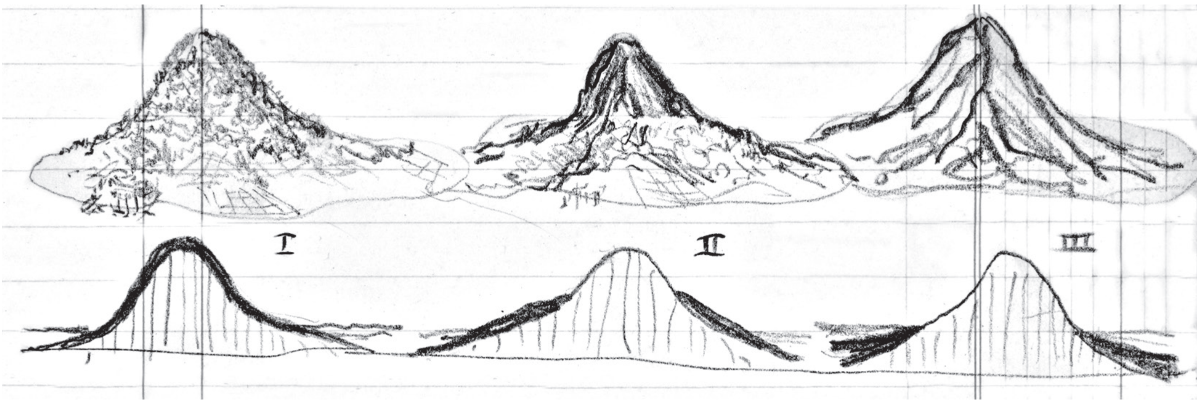


Figure 8.9 Sketch of mountain erosion in three steps.

8.7.3 Procedure in mining[41]

"So haben wir die relative Seltenheit der meisten Kulturmetalle aufzufassen als das Ergebnis einer groszartigen metalurgischen Schmeltz operation auf deren Schlacke wir leben".[42]

Rilke, "Das Erz hat heimweh."[43]

8.7.4 Efforts at concentration

[Baas Becking inserted Fig. 8.10.]

Fixation of atmospheric nitrogen.

8.7.5 Dissipation and consumption

Iron and tin.

Paper.

Bones and other phosphates.

Copper.

Coal.

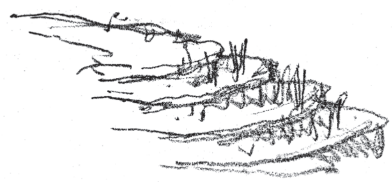


Figure 8.10 Vignette in margin (*circa* 3 × 3 cm) showing paddy fields.

8.7.6 Remedy

Soil-less culture.

40 Dr. Frans Beekman, The Hague Netherlands, wrote me:
"The *Handboek Geografie van Nederland IV* (1954) mentions clink and loss of soil when selling crops in Boskoop. 'Landing' of soil is regularly required (dredging, peat from elsewhere, duckweed and cow dung). This also prevents soil fatigue. Apparently in 1944 this was a problem that was discovered." (April 23, 2020).

41 In a manuscript *Seawater as a Chemical Milieu*, Baas Becking (1945-1946) remarked:
In ore-smelting, for example, the dissipation of the iron decreases. It is minimal just before the pig iron is made into plates. The tissued plates are made into tins. The tins are filled with products and *via* wholesaler and retailer they reach the consumer. Finally, the tins land on the rubbish heaps and corrode to oxides. Now dissipation is almost infinite and the process by which iron may be regenerated becomes increasingly laborious and increasingly less economic when dissipation increases.
Manuscript in private collection. See also description of dissipation by mining in Baas Becking (1942a).

42 The quote is from Beno Gutenberg (1889-1960), *Lehrbuch der Geophysik* (Gutenberg, 1929, p. 30).

43 Quoted from R.M. Rilke (1901), *Die Könige der Welt sind alt*:
Das Erz hat Heimweh. Und verlassen will es die Münzen und die Räder, die es ein kleines Leben lehren. Und aus Fabriken und aus Kassen wird es zurück in das Geäder der aufgetanen Berge kehren, die sich verschließen hinter ihm.

8.8 Predestination and Free Will[44]

Brunhes (1926, p. 610), Les causes de la dénaturalité.

v. Bemmelen, (1942), *Criminologie*.[45]

It's all a chequer board and of nights and days
Where destiny with men for pieces plays
Hither and thither moves, and mates and slays
And one by one back in the closet lays
Omar Khayyam.[46]

8.8.1 Introduction

[Baas Becking left this section blank.]

8.8.2 Nature and nurture

[Baas Becking left this section blank.]

8.8.3 Biological law

$$y = \frac{y_0}{\sigma\sqrt{2\pi}}.e^{-\frac{x^2}{2\sigma^2}}$$

8.8.4 Population laws

[Baas Becking inserted Fig. 8.11, without description. See also Section 5.1]

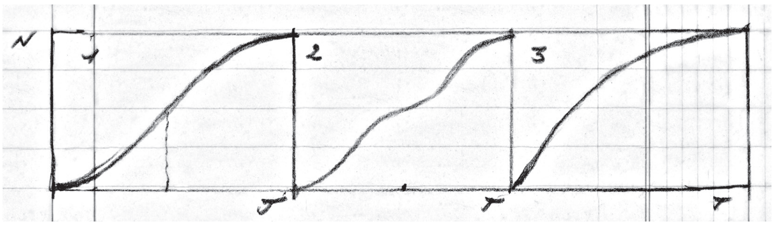


Figure 8.11 Three population curves.

8.8.5 Elements of predestination

[Baas Becking left this section blank.]

8.8.6 Elements of free will

[Baas Becking left this section blank.]

8.8.7 A new heaven and a new earth

[Baas Becking left this section blank.]

8.9 [Economic Botany]

A. de Candolle, *L'Origine des Plantes Cultivées*.[47]

8.9.1 Relation with plants[48]

Outline of Economic Botany:

8.9.1.a Food and food accessories

Maize, rice, wheat, rye, oats, barley.

a. Grains sorglucose [= sorbose].

b. Legumes. radish, pulse, lentil, beans, pear, soy bean, lime bean, peanut, alfalfa, clover, lupins.

c. Starch materials, potato, cassava, sweet potato, topinamboer, caladium, taro, sago, inulin.

d. Sugar, cane, beet, fruits, *etc*.

e. Fats, copra, oil palm, olive, peanut, cotton seed, rape-seed, bubassa, tallow, whale oil, *etc*.

f. Condiments, tobacco, coffee, tea, cocoa, cola, maté, guarana, mustard, pepper, cloves, nutmeg, etheriid oils, labiates, umbellifers, bay, ginger, curcuma.

[Baas Becking inserted Fig. 8.12.]

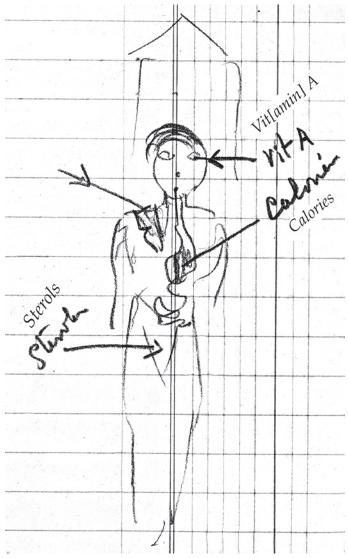


Figure 8.12 Drawing of person. The arrows indicate Vitamin A, calories, sterols.

44 See Baas Becking (1946b), in which the first section deals with 'Predestination and free will.'

45 Reference to Jacob Maarten van Bemmelen (1898-1982), Professor in Criminal Law and Criminal Proceedings University Leiden. In 1942 his main work, *Criminologie: Leerboek der Misdaadkunde* (van Bemmelen, 1942), was published. Van Bemmelen resigned in 1942. Later that year he was arrested as a hostage by the occupiers and imprisoned in St. Michielsgestel. He was released again in 1943 and went into hiding (Otterspeer, 2019).

After WWII, he argued that despite the horrific acts of the Germans, it is still legitimate to remain an opponent of the death penalty. He therefore argued that fundamental objections to the death penalty should not suddenly be dismissed because someone had done something disgusting. He believed that the integrity of life should be respected and that anyone who takes a life loses a piece of their own humanity. These fundamental objections were therefore the reason that he never wanted to sit in any college of special administration of justice. Van Bemmelen also had serious objections to the circumstances in which political offenders were held imprisoned after the war (around 100,000) and argued for the release of people suspected of lighter offenses (around 40,000).

46 The Rubaiyat of Omar Khayyam: *Quatrain XLIX*.

47 Alphonse Pyramus de Candolle (1806-1893), French-Swiss botanist. Baas Becking referred to Candolle (1882/1883), *Origine des Plantes Cultivées*, or a later edition of the book. The book of Candolle is a landmark for plant history, and it remains a model in its method and rich in data.

48 In the 1953 version of *Geobiology*, Baas Becking (1953a) remarked in Section *Man and Plants* (p. 711):

Plant and man are therefore in close symbiosis. Even if we could synthesise all necessary substances by means of a cheap source of energy (like sunlight) and thus acquired an "autotrophic" status independent of the organic environment, this great achievement might become a veritable 'Pyrrhic victory.' Outside the than completely urbanised world, there would be the desert, or the enormous patches of the 'green desert.' Man, thus estranged from nature, would sooner or later revise his directives and return to the green places which were once the veritable reasons for his existence, the city having created a mental desert in himself.

8.9.1.b Drugs

Papaver alcaloids, solanaceous alcaloids, serotonine, ephedrine, berberine *etc.*

Ipecacuanha.[49]

Senna, rhubarb, aloes, rhum, quillaja, shatavari, liquorice.[50]

Rad van avontuur. [Dutch 'Wheel of adventure'.]

8.9.1.c Dyes

Alisarin, rubia, word, indigo, pastel, blue-word, red-word, fuchsine, yellow-berries, heather.

8.9.1.d Tanning materials

Oak galls, oak basts, divi-divi, quebracho, wattle, cutch.

8.9.1.e Fibre materials

Coir, jute, renal, flax, hemp, roselle, java-jute, manila hemp, sisal, henequen [*Agave fourcroydes*], New Zealand flax, bow string hemp, piassava, cotton, capok, midouri [?],[51] substitutes, artificial cellulose.

8.9.1.f Paper materials

Soft wood, hard wood, esparto, rags, straw, rice straw, paper mulberry.

8.9.1.g Timber

Fir, cedar, pine, oak, mahogany, teak, eucalyptus, redwood.

8.9.1.h Cork

8.9.1.i Wax's, gums, resins

Canada balsum, terpentine, clamman, grains, expol, gum Arabic, pectins, agar.

8.9.1.j Animal products

Dairy, leather, horn, wool, honey, whalebone, bone, feathers, cochinillo, shells, pearls, mother of pearl (Troche).[52]

8.9.1.k Secondary technical changes

Milk wool, wood cellulose, cattle foods from strand.

8.9.1.l Causobioliths

Coal, peat, lignite, oil, asphalt, bitumen, ichthyol.

8.10 Summary and Conclusions

[Baas Becking left this section blank.]

49 Ipecacuanha, extract of the root of *Psychotria ipecacuanha*, a Rubiaceae, it contains emetic alkaloids cephaeline and emitine. Used as a home remedy for various purposes. The drug was already used in Europe in the 18th century. Misuse of ipecacuanha by patients with anorexia nervosa and bulimia has resulted in severe myopathy, lethargy, erythema, dysphagia, cardiotoxicity, and even death. In 1775, Joan Gideon Loten described the drug as "a poison, as Jalappa or Rhubarb, which taken in excess is also able to send someone ad patres". See Raat (2010, p. 380).

50 *Anthracene glycosides*: Aloes, dried latex of leaves of various *Aloes*; rhubarb, rhizome and roots of *Rheum officinale*; senna, dried leaves of *Cassia senna*. *Saponin glycosides*: shatavari, roots of *Asparagus racemosus*; liquorice, derived from *Glycyrrhiza glabra*; quillaja, derived from *Quillaja Saponaria.*

51 Possibly a reference to Elephant Ears Midori Sour (*Colocasia esculenta*), popular as annuals due to their rapid growth. Colocasia makes a dramatic impact to the landscape within just one growing season.
See https://www.elephantearsplants.com/elephantearsmidorisour.htm

52 Troche is a univalve shell.

9. DESCRIPTION OF NATURAL MILIEU

9.1 A Peatbog in Drenthe

Literature at Botanical Laboratory Leiden.[1]

[Four concentric circles.]

9.2 A Dune Lake on the Island of Voorne

Literature at Botanical Laboratory Leiden.[2]

9.3 Freshening of the Zuyderzee

Literature at Botanical Laboratory Leiden.[3]

(Baas Becking, 1936a).

9.4. A Desert Lake, Bumbunga[4]

[Baas Becking left this section blank.]

9.5 A Desert Salt Lake, Searles[5]

Rhopalophylla salina, Kirby, 34.8 % salt, 1934.

9.6 Solar Salt Works

Gersik Puthih, island of Madura.[6]

See literature!

Freshwater floating brine.

9.7 Volcanic Lake Kawah Tijwedédh

Literature L. Baas Becking. *Royal Academy*.[7]

9.8 Water of Unusual Composition[8]

To outline the so called forbidden area, are given below in % equivalent (data recalculated from Clarke, 1916).

1 Baas Becking and Nicolai (1934).

2 See Section 5.7.4.

3 In the 1953 version of *Geobiology*, Baas Becking (1953a) referred in the Section *Phosphorus* to the freshening of Zuyderzee (p. 528):

> When after the construction of the sea dyke at the north end of the Zuiderzee the freshening of the waters set in (Baas Becking, 1936a), a speedy increase of phosphate occurred after the decrease of the chlorinity below 2000 ppm. Values as high as 2 mg of phosphate *per* litre were observed due to the mass death of many fishes and other marine animals. Taking an average of 1 mg *per* litre this would amount to an accumulation of 1500 tons of phosphate corresponding to more than 2000 tons of collophane. This, however, only represented the soluble part of the phosphate. It may be seen, therefore, that the total accumulation would be several hundred times as large. An estuary or shallow littoral which becomes land locked may therefore well account for large accumulations of this mineral.

4 In the 1953 manuscript of *Geobiology* (p. 393-396), Baas Becking inserted a description of Lake Bumbunga which he visited March 27, 1936.

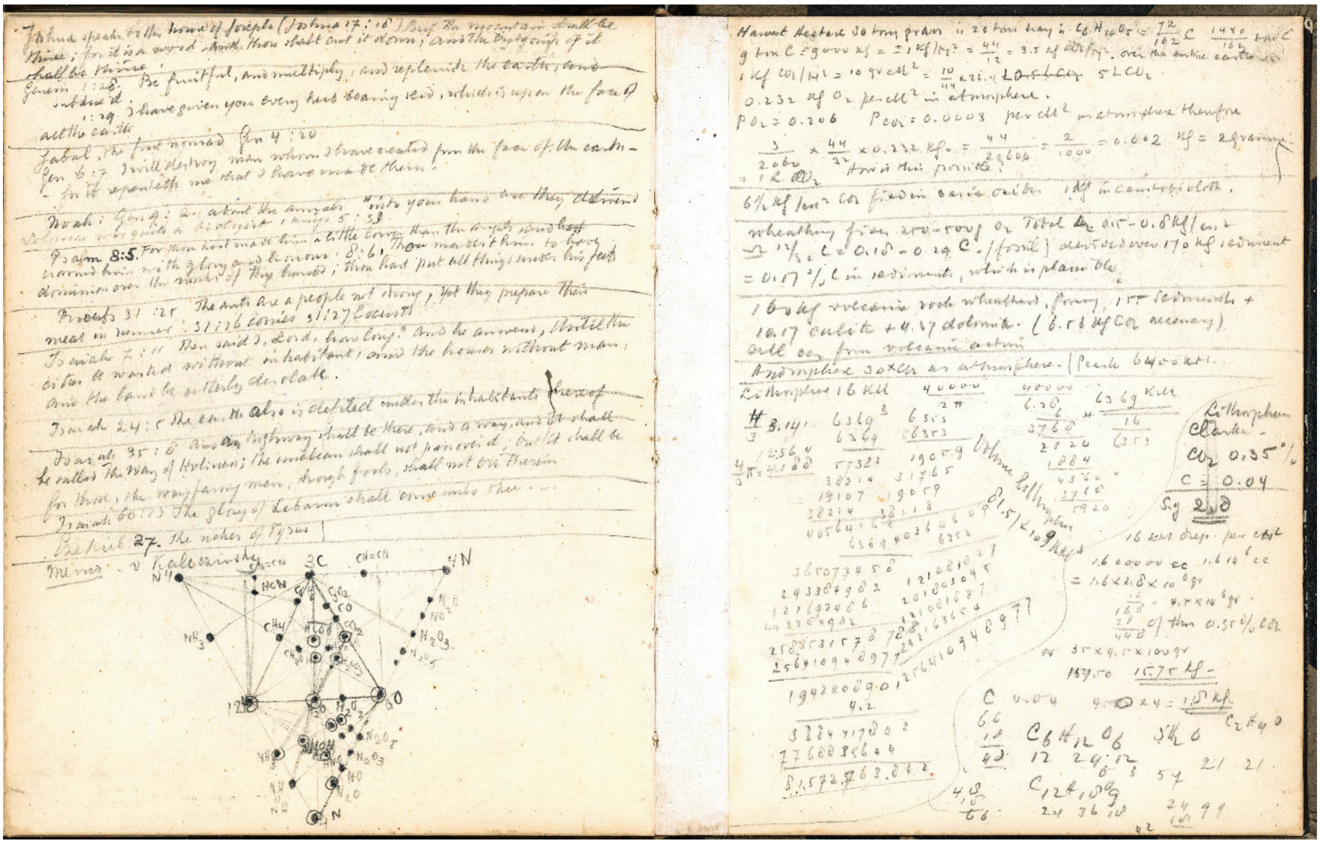
5 Baas Becking described experiments in Searles lake in *Geobiology* (1934 and 2016, p. 125). In the 1953 manuscript of *Geobiology* (Baas Becking, 1953a, p. 310-313) he inserted a description of Lake Searles.

6 In the 1953 manuscript of *Geobiology* (p. 358-361) Baas Becking inserted a description of the Governmental salterns at Gersik Putih, Madura, which he visited on July 4-11, 1936, together with Dr. J. Reuter.

7 Reference to Baas Becking (1938a). In the 1953 manuscript of *Geobiology* (1953a, p. 399) Baas Becking referred to this volcanic lake on the slope of the Patuha, Java. In the manuscript of *Geobiology* (1953a), he referred to Ruinen and Baas Becking (1938), Rhizopods living in unusual environments.

8 In the Table of Contents, Baas Becking mentioned the last section of the manuscript *as A Dutch Provincial Town*. Apparently, he changed his mind and inserted a section *Waters of Unusual Composition*.

Last pages of the manuscript Geobiology



This scan shows the last pages of the manuscript. The transcript can be found below.

Left page: [Quotations from the Bible (see transcription of the manuscript) and 2 D version of a 3 D tetrahedron or triangular pyramid, to depict the oxidation and reduction of carbon and nitrogen compounds.]

Joshua speaks to the tribes of Joseph (*Joshua* 17:18) but the mountain shall be thine; for it is a wood and thou shalt cut it down: and the outgoings of it shall be thine.[1]

Genesis 1:28 Be fruitful, and multiply, and replenish the earth, and subdue it.[2]

1:29 I have given you every herb bearing seed, which is upon the face of all the earth.

Jabal, the first nomad *Genesis* 4:20.[3]

Genesis 6:7 I will destroy man whom I have created from the face of the earth; [both man, and beast, and the creeping thing, and the fowls of the air;] for it repenteth me that I have made them.

1 *Joshua* 17:18 in the King James Bible version.
2 *Genesis* 1:28 and 29 in the King James Bible version.
3 And Adah bore Jabal: he was the father of such as dwell in tents, and of such as have cattle. *Genesis* 4:20 King James Bible version.

Noah: *Genesis* 9:2 About the animals. "Into your hand are they delivered."[4] Solomon was quite a biologist: 1 *Kings* 5:33.[5]

Psalm 8:5 For thou hast made him a little lower than the angels, and hast crowned him with glory and honour. 8:6. Thou madest him to have dominion over the works of thy hands; thou hast put all *things* under his feet.

Proverbs 30:25 The ants *are* a people not strong, yet they prepare their food in the summer; 30:26. Conies; 30:27. Locusts.[6]

Isaiah 7:11 Then said I, Lord, how long? And he answered, Until the cities be wasted without inhabitant, and the houses without man, and the land be utterly desolate.[7]

Isaiah 24:5 The earth also is defiled under the inhabitants thereof.

Isaiah 35:8 And a highway shall be there, and a way, and it shall be called The way of holiness; the unclean shall not pass over it; but it *shall be* for those: the wayfaring men, though fools, shall not err *therein*.

Isaiah 60:13 The glory of Lebanon shall come unto thee, the fir tree, the pine tree, and the box together, to beautify the place of my sanctuary; and I will make the place of my feet glorious.

Ezekiel 27 The riches of Tyrus.[8]

Right page: [Very rough calculation of carbon/CO_2 content in the atmosphere, hydrosphere and lithosphere.][9]

Harvest hectare 30 tons grass is 20 tons. Hay is $C_6H_{10}O_5$ = 72/162 C. [Harvest/ hectare is] 1440/162 tons C. [= 8.9 tons C/Ha = ±9 tons C/ Ha.] 9 tons C /Ha = 9000 kg C/Ha = ±1 kg C/m^2. [1 kg C/m^2 =] 44/12 kg CO_2/m^2 = 3.5 kg CO_2/m^2. Over the entire cont[inent].

1 kg CO_2/m^2 = 10 g CO_2/cm^2 = 10/44 × 22.4 Litres 0,5 Litres CO_2. 0.232 kg O_2 *per* cm^3 in atmosphere.

pO_2 = 0.206; pCO_2 = 0.0003 *per* cm^3 in atmosphere therefore

3/2060 × 44/22 × 232 kg CO_2/cm^3 = 44/20,600 = 2/1000 = 0.002 kg CO_2/cm^3 = 2 grams CO_2/ litre. How is this possible?

6 ½ kg CO_2/cm^3 fixed in basic oxides, 1 kg in caustobiolith.

Weathering fixes 250-500 g O_2/cm^3. Total O_2 fixation 0.5 – 0.8 kg O_2/cm^3 ≙ 12/30 kg C/cm^3 = 0.18 – 0.29 kg C/cm^3. (fossil) divided over 170 kg sediment = 0.17% C in sediments, which is plausible.

160 kg volcanic rock weathered, forming 155 sediments + 10.17 culite + 4.37 dolomite (6.56 kg CO_2 necessary). All are from volcanic action.

Hydrosphere 30 × CO_2 as atmosphere (Pearle 6,400 km^3).[10]

Lithosphere 16 km [follows a calculation of the volume of the lithosphere.]

Volume lithosphere 81.57 × 10^9 km^3.

Lithosphere Clarke (1916). CO_2 0.35%, <u>C = 0.04</u>%, S.G. <u>2.8</u>.

16 km deep *per* cm^3. 1,600,000 cc, 1.6 × 10^6 cc = 1.6 × 2.8 × 10^6 g = 4.5 × 10^6 g, thus 0.35% CO_2, or 35 × 4.5 × 100 g = 15.75 kg CO_2 and 1.8 kg C/. [or 0.0098 mg CO_2/cm^3 and 0.0011 mg C/cm^3]

---

4 *Genesis* 9:2 in the King James Bible version: And the fear of you and the dread of you shall be upon every beast of the earth, and upon every fowl of the air, upon all that moveth *upon* the earth, and upon all the fishes of the sea; into your hand are they delivered.

5 Reference to 1 *Kings* 4:33: And he spake of trees, from the cedar tree that *is* in Lebanon even unto the hyssop that springeth out of the wall: he spake also of beasts, and of fowl, and of creeping things, and of fishes.

6 Reference to *Proverbs* 31:25, 26 and 27, but the quotes are from *Proverbs* 30:26 and 30:27 in the King James Bible version:
> The conies *are but* a feeble folk, yet make they their houses in the rocks; The locusts have no king, yet go they forth all of them by bands.

7 Reference to *Isaiah* 7:11, the quote however is from *Isaiah* 6:11.

8 Baas Becking probably referred to *Ezekiel* 27.
In the Utrecht prison Baas Becking shared a cell with Professor Victor H. Rutgers. In the biographical sketch of Rutgers he wrote:
> I wrote about a city as an organism, with its energy production. He gave me to read *Ezekiel* 27, which describes the riches of Tyrus and when I spoke of the devastation that man is doing on earth, he showed me places from Isaiah, and we thought of the anciently destroyed land of Palestine and read the words of the prophet from my English bible: "The Earth is defiled by the inhabitants thereof." [Translated from Dutch AJPR]

Gaay Fortman (1946, p. 51-52).

9 Baas Becking made very rough calculations of the global yearly harvest production in kg CO_2/m^2. He made an estimate of CO_2 content in the atmosphere and compares that with CO_2 fixing by weathering and the formation of carbonic acid in ocean surface waters. He further gave an estimate of CO_2 in the hydrosphere, without a calculation. In the last part of the page, he made an estimate of the CO_2 and C content in the lithosphere. In his calculation he did not take the biosphere and the cycles of organic compounds of carbon into account. Baas Becking's calculations give the impression of simple pastime, a game of numbers. It is not a serious attempt to reliably depict the global carbon cycle. For more recent and reliable data see Romankevich and Vetrov (2013, *Masses of Carbon in the Earth's Hydrosphere*).

10 Clarke (1916).

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LOURENS BAAS BECKING was a pioneering microbial ecologist who coined the term "Geobiology" with the publication of his 1934 opus "Geobiologie of inleiding tot de milieukunde". Baas Becking was profoundly interested in organisms occupying extremes of temperature and salinity and is perhaps best remembered for his proposition that "Everything is everywhere, but the milieu (environment) selects". Presented here is a 1944 update of "Geobiologie", written in pencil over a seven week period, while Baas Becking was incarcerated for attempting to escape Nazi-occupied Netherlands. This volume, with its extensive detailed footnotes, brings us into the mind of one of the most important microbial ecologists of the 20th century. The volume also provides the most complete biography of Baas Becking and his fascinating life. We hope that this rather unusual *Geochemical Perspectives* will serve as both an important historical document as well as an insight into the state of microbial ecology and geobiology in the 1940s.