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

$$y = \frac{a}{(1 + e^{-bx})}$$

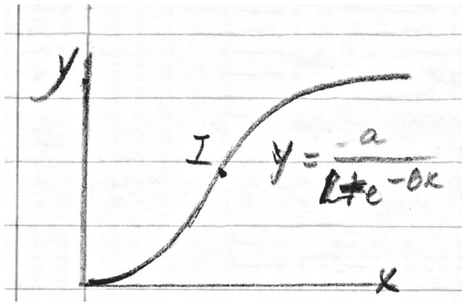

Figure 4.1 S-shaped growth curve.

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]

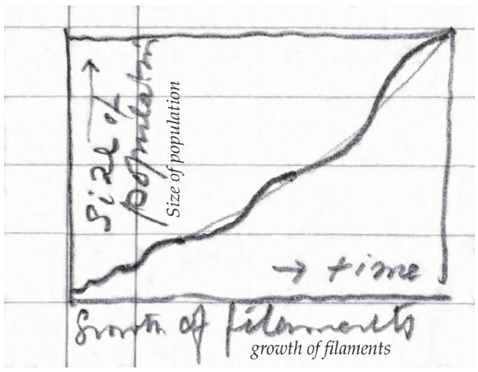

Figure 4.2 Series of S-shaped growth curves, growth of filaments.Y axis: Size of population; X axis: time.

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.

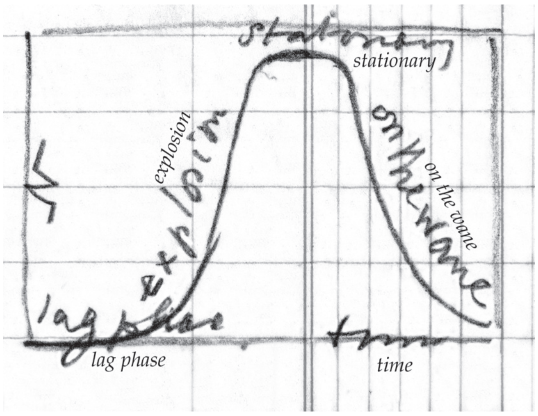

Figure 4.3 Example of epidemiological curve (size of population N against time) with phases: lag time, explosion, stationary, on the wane.

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.

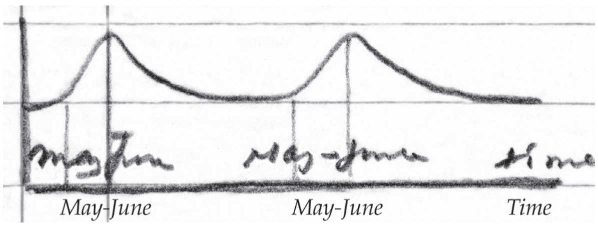

Figure 4.4 Seasonal increase and decrease of a bird population, peaks in numbers May/June (after Tinbergen, 1946).

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.

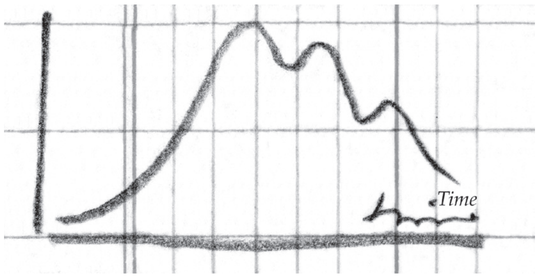

Figure 4.5 Example of the increase and decrease curve for a laboratory population of *Bacillus megaterium*.

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 are found that induce sexual activity, and so the culture will go through its developmental 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.

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.

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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.

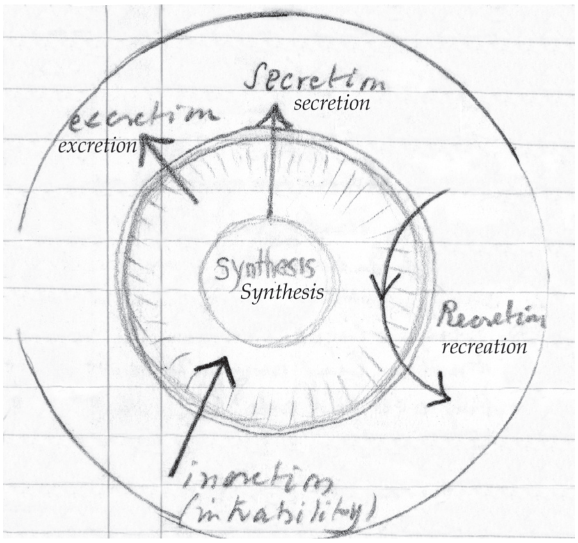

Figure 4.6 Schematic outline of secretion, excretion, recreation and incretion (intrability) of living cells.

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] …oes drag upward… …tion may even c… …port on Krakatoa, and the report of Verbeek and Ferzenaar).[25]

24 Reference to Australian aboriginal name 'Willy Willy', or 'Dust Devil', a strong, well formed, and relatively long lived whirlwind.

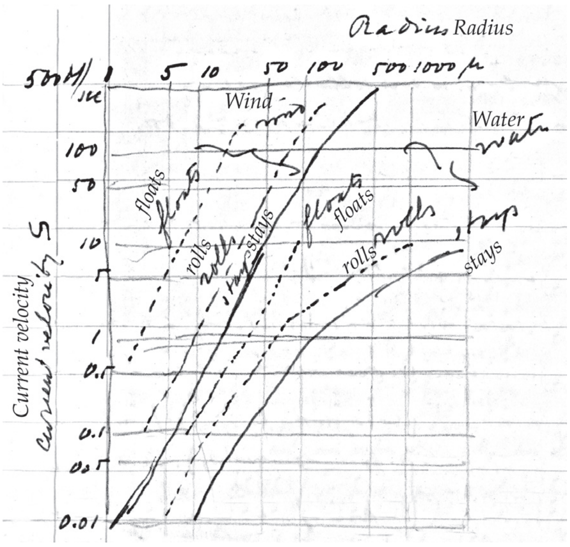

Figure 4.7 Transport limits for falling and rolling particles in air and water (S in m/sec) and grain sizes (in μ). From left to right: transport limit of falling particles in air ('floats'); transport limit faling particles in air ('rolls'); roll limit in air ('stays'); transport limit falling particles 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							
5			Radio waves				
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.

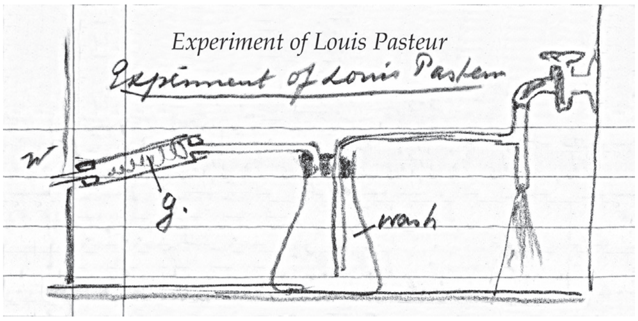

Figure 4.8 Experiment of Louis Pasteur (1861): W = outside air, g = gum cotton, the conical flask contains 'wash'.

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

$$r^3 (d-d').c = kv^n r^2$$

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

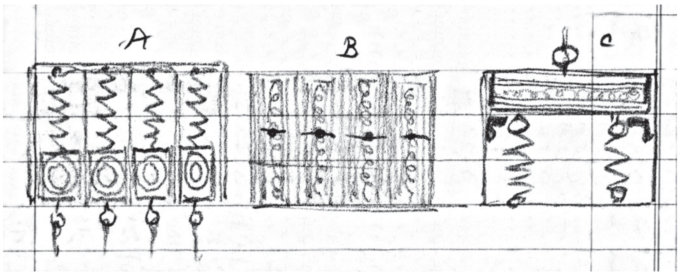

Figure 4.9 Van Overeem's (1936, 1937) sampling apparatus for aeroplankton, longitudinal section.

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).

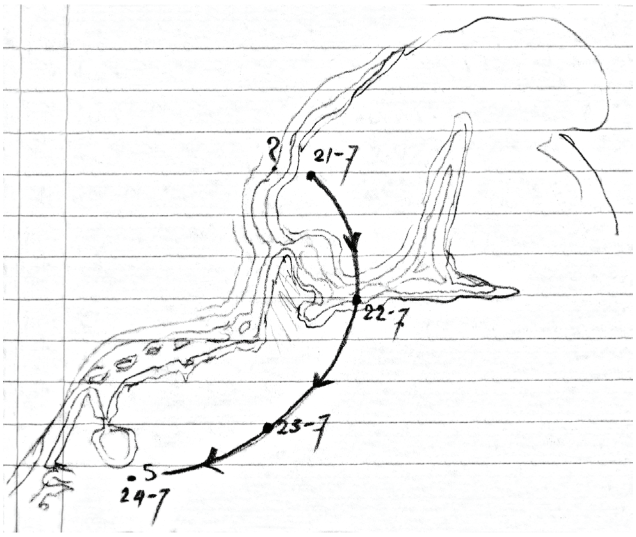

Figure 4.10 Windtracks from Bergen (Norway) to Soesterberg (Netherlands), 25 August - 28 August 1936.

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).]

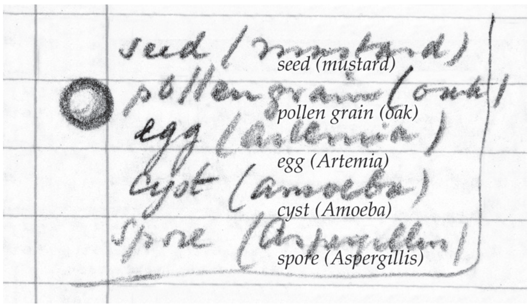

Figure 4.11 Small sketch in the margin of seed/mustard, pollen grain (oak), egg (*Artemia*), cyst (*Amoeba*), spore (*Aspergillis*).

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 to extreme temperatures. Dickson *et al*. (1919) kept the spores of *Bacillus botulinus* for 4 hours in an oil bath at 150 °C. Not only bacteria but also moulds, and even beetles persist at temperatures of liquid hydrogen (-230 °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).

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,

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.

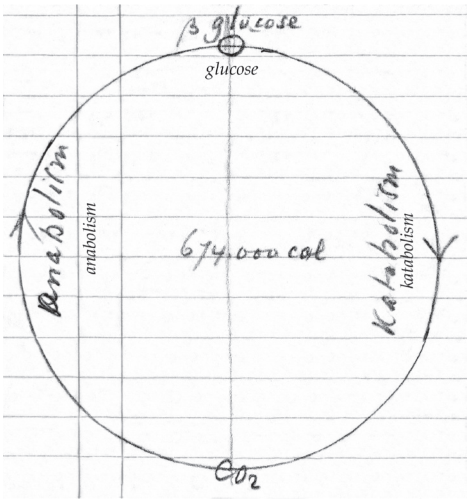

Figure 4.12 Energy potential for complete oxidation of glucose (catabolism) and synthesis of glucose from CO_2 (anabolism).

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.

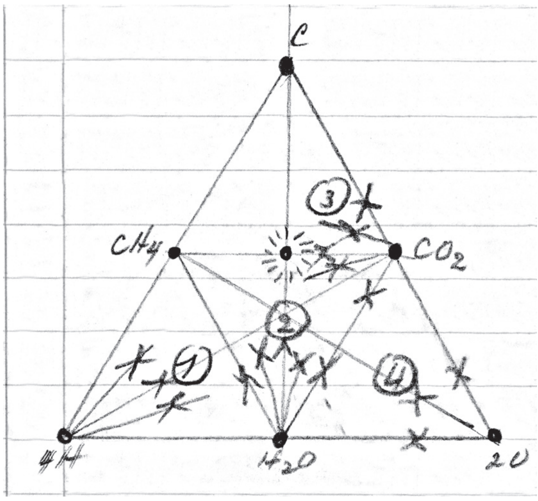

Figure 4.13 Equilateral triangular plot with compounds C – 4H – 2O representing the glucose metabolism. 1. Hydrogenation and de-hydrogenation. 2. Hydration and de-hydration. 3. Carboxylation and de-carboxylation. 4. Oxidation and de-oxidation.

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.

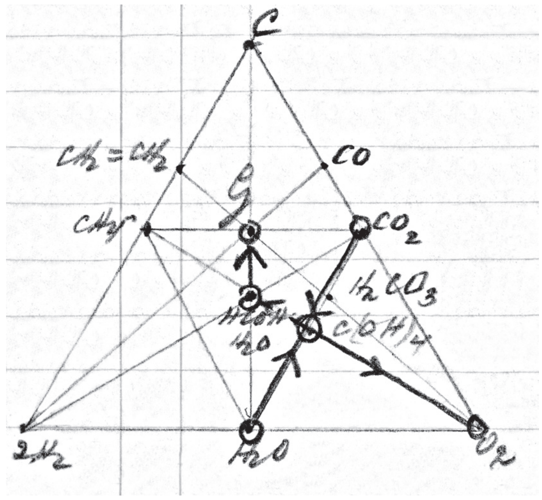

Figure 4.14 Equilateral triangular plot with compounds C – 4H – 2O representing the synthesis of glucose (G) from CO_2 and $2H_2O$ by photosynthesis.

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 4hν [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

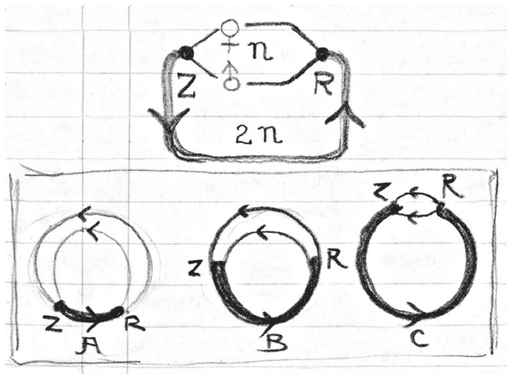

Figure 4.15 Schematic representations of the life cycles of various organisms: Z = zygote R = reduction division of sex cell.

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]

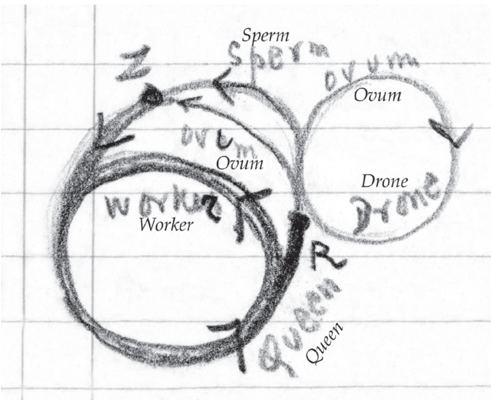

Figure 4.16 Schematic representations of life cycle of the honey bee, showing the reproduction of the queen, worker and drone.

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.

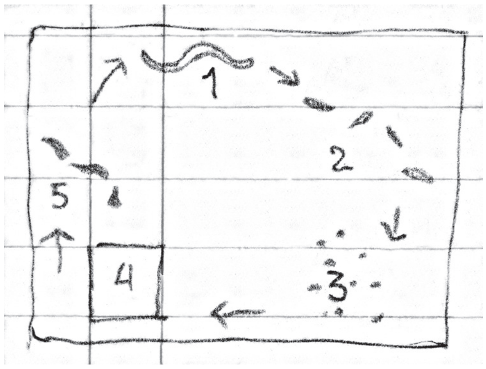

Figure 4.17 Suggested life cycle of bacteria, algae and protozoa.

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.]

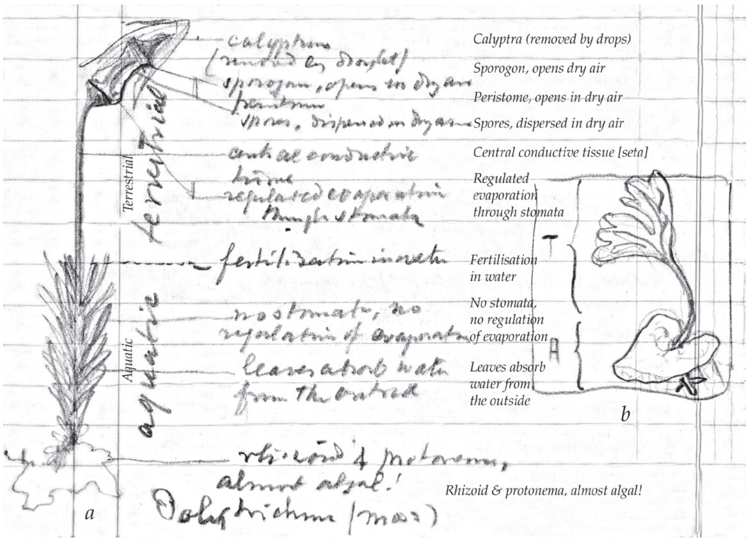

Figure 4.18 **(a)** Life cycle of *Polytrichum* (haircap or hair moss). **(b)** Life cycle of ferns (A = Aquatic, haploid generation; T = Terrestrial, diploid generation).

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 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!

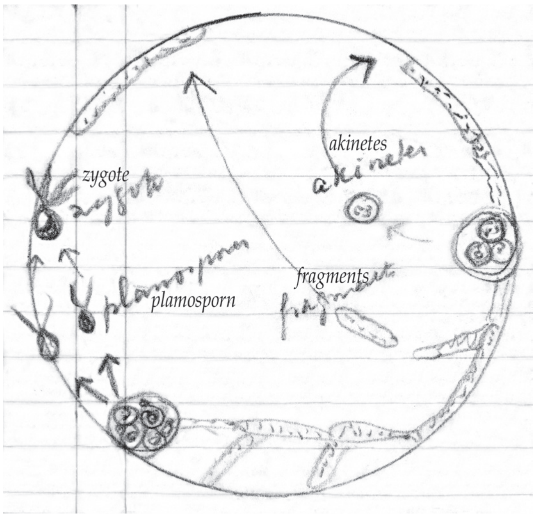

Figure 4.19 Baas Becking's version of the Life cycle of *Ctenocladus circinnatus*. After Ruinen (1933).

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).

REFERENCES SECTION 4

Abbot, J.K., Nordén, A.K., Hansson, B. (2017) Sex chromosome evolution: historical insights and future perspectives. *Proceedings of the Royal Society B* 284, 20162806.

Algera, L. (1932) Energiemessungen bei Aspergillus niger mit Hilfe eines automatischen Mikro-Kompensations Calorimeters. PhD Thesis, Groningen.

Arisz, W.H. (1943) Het actief en passief opnemen van stoffen door Vallisneria. *Verslagen Nederlandse Akademie van Wetenschappen. Afdeling Natuurkunde* 52, 639-645.

Baas Becking, L.G.M. (1921b) The origin of the vascular structure in the genus Botrychium. *Recueil des Travaux Botaniques Néerlandais* 18, 333-372.

Baas Becking, L.G.M. (1924a) Anthonie van Leeuwenhoek, immortal dilletant (1632-1723). *The Scientific Monthly* 18, 547-554.

Baas Becking, L.G.M. (1924b) The source of energy of the sulphur bacteria. *Proceedings of the Society for Experimental Biology and Medicine* 22, 127-129.

Baas Becking, L.G.M. (1928b) On organisms living in concentrated brine. *Nederlandsch Tijdschrift voor de Dierkunde* 3, 6-9.

Baas Becking, L.G.M. (1931a) Salt effects on swarmers of Dunaliella viridis Teod.' *Journal of General Physiology* 14, 765-779.

Baas Becking, L.G.M. (1931b) Gaia of Leven en Aarde. Rede uitgesproken bij het aanvaarden van het ambt van gewoon hoogleeraar aan de Rijksuniversiteit te Leiden op woensdag den 28ste januari 1931. Martinus Nijhoff, 's-Gravenhage.

Baas Becking, L.G.M. (1934) Geobiologie of Inleiding tot de Milieukunde. W.P. van Stockum, Den Haag.

Baas Becking, L.G.M. (1935) Zwaar water en thermotolerantie. *Verslagen van de gewone vergaderingen Koninklijke Nederlandse Akademie van Wetenschappen, Amsterdam*. Afdeeling Natuurkunde 44, 96-98.

Baas Becking, L.G.M. (1936a) The Zuiderzee, its past. present and future. Proceedings 6th International Botany Congress Amsterdam, 2-7 Sept. 1935. Brill, Leiden 1, 108-121.

Baas Becking, L.G.M. (1942-1943) The Kingdom of this World. Handwritten manuscript (unfinished), Leiden University Library BPL 3233.

Baas Becking, L.G.M. (1946a) On the analysis of sigmoid curves. *Acta Biotheoretica* 8, 42-59.

Baas Becking, L.G.M. (1953a) Geobiology. (Typescript with handwritten notes 830 pages by Baas Becking. The original manuscript was given to the KNAW Amsterdam in 1977 and is lost now. Copies of the manuscript are in the University libraries of Leiden, Nijmegen and Wageningen. In the library of NIOO KNAW Wageningen there is a bound copy of Geobiology formerly owned by the freshwater ecologist Dr H.L. Golterman (1928-2018)).

Baas Becking, L.G.M. (2016) Baas Becking's Geobiology, or Introduction to environmental science. Edited by D.E. Canfield. Translation of Geobiologie 1934. Wiley Blackwell. https://doi.org/10.1002/9781118295472

Baas Becking, L.G.M., Galliher, E.W. (1931) Wall structure and mineralization in coralline algae. *Journal of Physiological Chemistry* 35, 467-479.

Baas Becking, L.G.M., Parks, G.S. (1927) Energy relations in the metabolism of autotrophic bacteria. *Physiological Reviews* 7, 85-106.

Baas Becking, L.G.M., Hanson, E.A. (1937) Een mogelijk mechanisme der koolzuurassimilatie bij de groene plant. Verslagen KNAW afd. *Natuurkunde* 46, 83-85.

Baas Becking, L.G.M., Wood, J.G. (1937) Notes on convergence and Identity in relation to environment. *Blumea: Biodiversity, Evolution and Biogeography of Plants* 2, 329–338.

Backer, C.A. (1929) The problem of Krakatao, as seen by a botanist. Weltevreden, The Hague, Visser & Co, M. Nijhoff.

Barlow, P.W., Fisahn, J. (2012) Lunisolar tidal force and the growth of plant roots, and some other effects on plant movements. *Annals of Botany* 110, 301-318.

Becquerel, P. (1925) La suspension de la vie des graines dans le vide à la température de l'hélium liquide. *Comptes Rendus de l'Académie des Sciences, Paris* 181, 805-807.

Becquerel, P. (1935) Recherches de physiologie végétale dans les hauts vides et aux basses températures. Masson, Paris.

Bergmann, M. (1934) Synthesis and Degradation of Proteins in the Laboratory and in Metabolism. *Science*. 79, 439-445.

Boedijn, K.B. (1925) Der Zusammenhang zwischen den Chromosomen und Mutationen bei Oenothera lamarckiana. PhD Thesis, Amsterdam.

Boedijn, K.B. (1929) Beitrag zur Kenntnis der Pilzflora von Sumatra. *Recueil des travaux botaniques néerlandais* 26, 396-439.

Boeke, J. (1941) Problemen der onsterfelijkheid: leven, dood, levensduur en onsterfelijkheid biologisch beschouwd. Meulenhoff, Amsterdam.

Boone, E., Baas Becking, L.G.M. (1931) Salt effects on eggs and nauplii of Artemia salina L. *Journal of General Physiology* 14, 753-763.

Bower, F.O. (1923-1928) The Ferns. Cambridge University Press.

Brouwer, G. (1925) On the periodical movements of the Primary leaves of Canavalia ensiformis. D.C. *Verhandelingen Koninklijke Nederlandse Akademie van Wetenschappen* 19, 515-523. PhD Thesis, Utrecht.

Brouwer, G. (1926) *De periodieke bewegingen van de primaire bladen bij Canavalia ensiformis*. H.J. Paris, Amsterdam, 120 pp. Translated as: *The periodic movements of the primary leaves of* Canavalia ensiformis. NASA Technical Translation F-13,089.

Brown, H.T., Escombe, F. (1900) Static diffusion of gases and liquids in relation to the assimilation of carbon and translocation in plants. *Annals of Botany* 14, 537-542.

Bunker, H.J. (1936) Review of the Physiology and Biochemistry of the Sulphur Bacteria. H.M.S.O., London.

Chen, B. (2018) A non-metaphysical evaluation of vitalism in the early twentieth century. *History and Philosophy of the Life Sciences* 40, 50. https://doi.org/10.1007/s40656-018-0221-2

Chibnall, A. (1939) Protein metabolism in plants. Yale University Press, New Haven.

Correns, C.W. (1939) Die Sedimentgesteine. In: Barth T.F.W., Correns C.W., Eskola P. (Eds) *Die Entstehung der Gesteine*. Springer, Berlin, Heidelberg, 116-262. https://doi.org/10.1007/978-3-642-86244-1_2

Cushman, J.A., Schenck, H. (1928) Two foraminiferal faunules from the Oregon tertiary. University of California Press, Berkeley, CA.

De Candolle, De (1855) Géographie Botanique Raisonnée. V. Masson, Paris.

Dickson, E.C., Burke, G.S., Engelena, S.,Ward, S. (1919) Botulism. A study of the resistance of the spores of Bacillus botulinus to various sterilizing agencies which are commonly employed in the canning of fruits and vegetables. *Archives of Internal Medicine (Chicago)* 24, 581-599.

Deichmann, U. (1996) Biologists under Hitler. Harvard University Press.

Deichman, U. (2001) Flüchten, Mitmachen, Vergessen. Chemiker und Biochemiker in der NS-Zeit. Wiley-VCH, 329-336.

Diels, L., Samuelsson, G., Hannig, E. Winkler, H. (1926-1931) Die Pflanzenareale. Sammlung kartographischer Darstellungen von Verbreitungsbezirken der lebenden und fossilen Pflanzen-Familien, -Gattungen und – Arten. Gustav Fischer, Jena.

Erréra, L. (1886) Pourquoi les éléments de la matière vivante ont-ils des poids atomiques peu élevés? *Malpigia* 1.

Feekes, W. (1936) De ontwikkeling van de natuurlijke vegetatie in de Wieringermeerpolder, de eerste groote droogmakerij van de Zuiderzee. *Nederlandsch Kruidkundig Archief* 46, 1-296.

Free, E.E. (1911) The movement of soil by the wind. US Dept Agriculture. Bureau of Soils. Bulletin 68.

Frey-Wyssling, A. (1938) Submikroskopische Morphologie des Protoplasmas und seiner Derivate. Berlin Bornträger.

Fritsch, F.E. (1927) A treatise on the British Freshwater Algae. Cambridge University Press.

Gaffron H. (1939) Reduction of CO_2 with H_2 in green plants. *Nature* 143, 204-205.

Gaffron H. (1940) Carbon dioxide reduction with molecular hydrogen in green algae. *American Journal of Botany*27, 273-283.

Gibb, J.A. (2008) L. Tinbergen's hypothesis of the role of specific search images. *Ibis* 104, 106-111.

Guppy, H.B. (1917) Plants, seeds, and currents in the West Indies and Azores; the results of investigations carried out in those regions between 1906 and 1914. Williams & Norgate, London.

Grabau, A.W. (1913) Principles of Stratigraphy. A.G. Seiler & Co, New York.

Harmsen, G.W. (1946) Onderzoekingen over de aerobe celluloseontleding in den grond. Wolters, Groningen. PhD thesis, Groningen.

Hehn, V. (1873) Das Salz. Eine kulturhistorische Studie. Gebrüder Borntraeger, Berlin.

Henderson, L.J. (1913) The fitness of the environment. An inquiry into the biological significance of the properties of matter (Reprint with introduction by George Wald (1970)) Peter Smith, Gloucester, MA.

Henrici, A.T. (1939) The Biology of Bacteria. Second edition. D.C. Heath and Co. New York, 132-137.

Heringa, G.C. (1961) Prof. dr. Jan Boeke en zijn betekenis voor de neurohistologie. *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afdeling Natuurkunde. Tweede reeks* 53, 31 pp.

Hes, J.W. (1937) Zur Stoffwechselphysiologie von Nitrosomonas. PhD Thesis, Groningen.

Hofmeister, W.F.B (1851) Vergleichende Untersuchungen der Keimung, Entfaltung und Fruchtbildung höherer Kryptogamen und der Samenbildung der Coniferen. Verlag von Friedrich Hofmeister, Leipzig.

Hubert, B. (1935) The physical state of chlorophyll in the living plastid. *Recueil des Travaux Botaniques Néerlandais* 32, 323-390.

Humphreys, W.J. (1929) Physics of the air. New York McGraw-Hill. A reprint of Humphrey's contributions in the Journal of the Franklin Institute 1917, 1918, 1919 and 1920.

Jacobs, M. (1984) Herman Johannes Lam (1892-1977). Rodopi, Amsterdam.

Joly, M. (1840) Histoire d'un petit Crustacé (Artemia salina Leach), auquel on a faussement attribué la coloration en rouge des marais salans méditerranéens, suivie de recherches sur la cause réelle de cette coloration. *Annales des Sciences Naturelles Series 2* 13, 225-290.

Kingma Boltjes, T.Y. (1934) Onderzoekingen over nitrificeerende bacteriëen. PhD Thesis, Delft. W.D. Meinema.

Kleinhoonte, A. (1929) Ueber die durch das Licht regulierten Bewegungen der Canavalia-Blätter. *Archives Néerlandaises des Sciences* IIIb 5, 1.

Kleinhoonte, A. (1932) Untersuchungen über die autonomen Bewegungen der Primärblätter von Canavalia ensiformis DC. *Jahrbücher für Wissenschaftliche Botanik* 75, 679-725.

Koningsbergen, V.J. (1963) Levensbericht L.G.M. Baas Becking. *Jaarboek Koninklijke Nederlandse Akademie van Wetenschappen*1962-1963, 369-375.

Kuenen, D.J., Baas Becking, L.G.M. (1938) Historical notes on Artemia salina (L.) *Zoölogische Medelingen* 20, 222-230.

Lanjouw, J. (1949) In Memoriam H. Uittien. *Nederlandsch Kruidkundig Archief Series 3* 56, 58-68.

Lebedev, P.N. (1901) Untersuchungen über die Druckkräfte des Lichtes. *Annalen der Physik* 6, 433-458.

Lipman, C.B. (1932) Are there living bacteria in stony meteorites (aerolites)? *American Museum Novitales* 588, 1-19.

Löhnis, F. (1921) Studies upon the life cycles of the bacteria. *Memoirs of the National Academy of Sciences* 16, 1-252.

Lotka, A.J. (1924) Elements of Physical Biology. Williams & Wilkins, Baltimore.

Luckiesch, M. (1922) Ultraviolet Radiation: Its Properties, Production, Measurement, and Applications. Van Nostrand, New York.

Lütjeharms, W.J. (1937) Over de duinen van Parangtritis ten zuiden van Djokja. *De Tropische natuur* 26, 85-92.

Meier, F.C., Lindbergh, C.A. (1935) Collecting micro-organisms from the Arctic Atmosphere. *The Scientific Monthly* 40, 5.

Melis, A., Happe, T. (2004) Trails of green alga hydrogen research – from Hans Gaffron to new frontiers. *Photosynthesis Research* 80, 401-409.

Mills, M. (2012) Trained judgement, intervention, and the biological gaze: How Charles Sedgewick Minot saw senescence. In: Anderson, N., Dietrich, M.R. (Eds.) *The educated eye. Visual culture and pedagogy in the life sciences.* Dartmouth College Press, 14-43.

Minot, C.S. (1891) Senescence and Rejuvenation. First paper: on the weight of Guinea Pigs. *Journal of Physiology* 12, 97-192.

Minot, C.S. (1908) The problem of age, growth, and death. A study of cytomorphosis. Based on lectures at the Lowell Institute March 1907. G.P. Putnam's Sons, London.

Miquel, M.P. (1883) Les Organismes vivants de l'atmosphère. Gauthier-Villars, Paris.

Milne, J. (1892) A Dust Storm at Sea. *Nature* 46, 128. https://doi.org/10.1038/046128a0

Molisch, H. (1917) Gesundheitsschädlicher Biofeinstaub: Die Biologie des atmosphärischen Staubes (Aeroplankton) Populärer Vortrag von Dr. Hans Molisch gehalten den 6. Dezember 1916 im Verein zur Verbreitung naturwissenschaftlicher Kenntnisse in Wien.

Molisch, H. (1921) Pflanzenphysiologie. Jena, G. Fischer.

Morgan, T.H. (1909) A biological and cytological study of sex determination in phylloxerans and aphids. *Journal of Experimental Zoology* 7, 239-351.

Nickelsen, K. (2007) Otto Warburg's first approach to photosynthesis. *Photosynthesis Research* 92, 109-120.

Nicolai, E., Baas Becking, L.G.M. (1935) Einige Notizen uber Salzflagellaten. *Archiv für Protistenkunde* 85, 319-328.

Paravicini, E. (1918) Zur Frage des Zellkernes der Bakterien. *Zentralblatt für Bakteriologie und Parasitenkunde I* 48, 337-340.

Pasteur, L. (1861) Mémoire sur les corpuscules organisés qui existent dans l'atmosphere. Examen de la doctrine des générations spontanées. *Annales des Sciences Naturelles Zoologie Series 4* 16, 5-98.

Rahm, P.G. (1924) Weitere physiologische Versuche mit niederen Temperaturen. *Verhandlungen der Deutschen Zoologischen Gesellschaft* 29, 106-111.

Richter, R.J. (1931) Tierwelt und Umwelt im Hunsrückschiefer; zur Entstehung eines schwarzen Schlammsteins. *Senckenbergiana* 13, 299-342.

Roelofsen, P.A. (1934) On the metabolism of the purple sulphur bacteria. *Proceedings* of the *Koninklijke Nederlandse Akademie van Wetenschappen* 37, 660-669.

Ruinen, J. (1933) Life cycle and environment of Lochmiopsis sibirica Woron. *Recueil Des Travaux Botaniques Néerlandais* 30, 725-797.

Ruinen, J. (1938a) Notizen über Ciliaten aus konzentrierten Salzgewässern. *Zoologische Mededeelingen* 20, 243-256;

Ruinen, J. (1938b) Notizen über Salzflagellaten. II. Ueber die Verbreitung der Salzflagellaten. *Archiv für Protistenkunde* 90, 210-258.

Sandon, H. (1927) The composition and distribution of protozoan fauna of the soil. Oliver & Boyd, Edinburgh.

Schimper, A.F.W. (1898) Pflanzengeographie auf physiologischer Grundlage. Gustav Fischer, Jena.

Schmidt, J. (1923) The Breeding Places of Eel. *Philosophical Transactions of the Royal Society B* 211, 179-208.

Schuffelen, A.C., Loosjes, R. (1942a) The importance of the growth medium for absorption of cations by plants (a working hypothesis). *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* 45, 726-733.

Schuffelen, A.C., Loosjes, R. (1942b) The influence of the ion activity and ion concentration in the medium on absorption of cations by plants. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* 45, 944-952.

Shelford, V.E. (1929) Laboratory and Field Ecology: the responses of animals as indicators of correct working methods. Williams & Wilkins Comp.

Sinia, H.R. (1938) Zur Phylogenie der Fiederblätter der Bursaceeen und verwandter Familien. Brill, Leiden.

Smith, G.M. (1933) The Fresh-water Algae of the United States. McGraw-Hill.

Stephenson, M. (1930) Bacterial Metabolism. Longmans, Green & Co, London.

Stephenson, M., Strickland, L.H. (1931) 'XXVIII Hydrogenase, II. The reduction of sulphate to sulphide by molecular hydrogen'. *Biochemistry Journal* 25, 215-220.

Straub, J. (1930) Stationaire toestanden aan dode membranen. *Chemisch weekblad* 27, 672-674.

Straub, J. (1933) Membrangleichgewichte und harmonien. *Kolloid-Zeitschrift* 64, 72-83.

Straub, J. (1951) Over abnormale diffusie [On anomalous diffusion. The generation of harmonic concentration quotients at a charged membrane during diffusion of a single ion]. A presentation for the meeting of the *Nederlandse Vereniging voor Biochemie* on May 19th, 1951.

Sudry, L. (1912) Expériences sur la puissance de transport des courants d'eau et des courants d'air. *Annales de l'Institut Océanographique* t44, 68 pp., Paris.

Swammerdam, J. (1669) Historia Generalis Insectorum. Meinardus van Dreunen, Utrecht.

Symons, G.J. (Ed.) (1888) The Eruption of Krakatoa, and subsequent phenomena. Report of the Krakatoa Committee of the Royal Society. Trubner & Co., London.

Takagi, Y., Kitsunezaki, S., Ohkido, T., Komori, R. (2005) How Paramecium cells die under a cover glass? *Japanese Journal of Protozoology* 38, 153-161.

Tamiya, H. (1932) Zur Theorie des respiratorischen Quotienten nebst einer Bemerkung über den Einfluß der oxydoreduktiven Zellvorgänge auf den Gaswechsel der Zellen. *Acta Phytochimica (Tokyo)* 6, 227.

Tex, E. den (1974) Levensbericht I.M. van der Vlerk. *Jaarboek 1974 Koninklijke Nederlandse Akademie van Wetenschappen* 190-195.

Thornton, I.W.B. (1996) Chapter 6, The "Krakatau Problem". In: *Krakatau, the destruction and reassembly of the island ecosystem*. Harvard University Press, Cumbreland, Rhode Island, 78-96.

Thoulet, J. (1908a) Origin éolienne des minéraux fins contenus dans les fonds marins. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Paris* 146, 1346-1348.

Thoulet, J. (1908b) De l'influence de la déflation sur la constitution des fonds océaniques. *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, Paris* 147, 1363-1365.

Tinbergen, L. (1946) De Sperwer als roofvijand van zangvogels. Brill, Leiden.

Treibs, A.E. (1936) Chlorophyll- und Häminderivate in organischen Mineralstoffen. *Angewandte Chemie* 49, 682-686.

Uittien, H. (1929) Ueber den Zusammenhang zwischen Blattnervatur und Sprossverzweigung. *Recueil des Travaux Botaniques Néerlandais* 25, 390-483.

Van Niel, C.B. (1932) On the morphology and physiology of the purple and green sulphur bacteria. *Archives of Microbiology* 3, 1-112.

Van Steenis-Kruseman, M.J., van Steenis, C.G.G.J. (1950) Malaysian Plant Collectors and Collections being a Cyclopaedia of botanical exploration in Malaysia and a guide to the concerned literature up to the year 1950. *Flora Malesiana - Series 1, Spermatophyta* 1, 2-639.

Van Steenis-Kruseman, M.J. (1990) Verwerkt Indisch Verleden. Oegstgeest.

Van Overeem, M.A. (1936) A sampling-apparatus for aëroplankton. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* 33, 981-990.

Van Overeem, M.A. (1937) On green organisms occurring in the lower troposphere. *Recueil des Travaux Botaniques Néerlandais* 34, 388-442.

Verbeek, R.D.M. (1884) The Krakatoa Explosion. *Nature* 30, 10-15.

Verbeek, R.D.M. (1886) Krakatau. Government Printing Office, Batavia.

Vernadsky, V.I. (1924) La Géochemie. Felix Alcan, Paris.

Von Marilaun, A.K.R. (1895-1896) The natural history of plants, their forms, growth, reproduction, and distribution. Holt, New York.

Warburg, O., Negelein, E. (1922) Ueber den Energieumsatz bei der Kohlensäureassimilation. *Zeitschrift für Physikalische Chemie* 102, 235-266.

Warburg, O., Negelein, E. (1923) Ueber den Einfluss der Wellenlänge auf den Energieumsatz bei der Kohlensäureassimilation. *Zeitschrift für Physikalische Chemie* 106, 191-218.

Warren, H., Kuenen, D., Baas Becking, L.G.M. (1938) On the relation between internal and external medium in Artemia saline (L) var. principalis Simon. *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen* 41, 873-878.

Wildeman, É.A.J. de (1900) Les algues de la flore de Buitenzorg: essai d'une flore algologique de Java. E.J. Brill, Leide.

Wilkening, K. (2011) International transport of dust: Science and policy, pre-1800s to 1967. *Environment and History* 17, 313-339.

Wilkinson, D.M., Creevy, A.L., Valentine, J. (2012) The past, present and future of soil protist ecology. *Acta Protozoologica* 51, 189-199.

Winogradsky, S. (1887) Ueber Schwefelbacterien. *Botanische Zeitung* 45, 489-507.

Winogradsky, S. (1922) Eisenbakterien als Anorgoxydanten. ***Zentralblatt für Bakteriologie*** 2, 57, 1-21.

Woodruff, L.L. (1922) Foundations of Biology. Macmillan.

Yamazaki, A., Nishimiya, Y., Tsuda, S., Togashi, K., Munehara, H. (2019) Freeze tolerance in sculpins (Pisces; Cottoidae) inhabiting north pacific and arctic oceans: antifreeze activity and gene sequences of the antifreeze protein. *Biomolecules* 9, 139.