Phytosemiotics

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Introduction

The problem

The problem of this essay is to establish phytosemiotics, i.e., the semiotics of plants, as an area of inquiry intosign processes, parallel and on an equal footing with anthroposemiotics, the study of human communication, and zoosemiotics (Sebeok 1963, 1972), the study of sign processes occurring within and between species of animals, the three areas forming together the discipline of 'biosemiotics'.

Background of the problem

Subjective interest For three years, I have been working, in my capacity as a psychologist and semiotician, in an interdisciplinary team together with a designer, a gardener, and a physician in an experiment in living and working among plants. The designer from this team moved, four years ago, into a normal commercial greenhouse that was empty at the time. After a preliminary failure with 'laissez-faire' gardening and tropical vegetation, he planted, with the help of the gardener, a selection of subtropical plants around small platforms used for office work, sleeping, cooking, and sitting. These plants remain green all year round — regardless of the presence of snow and frost outside — if the greenhouse is moderately heated. The designer had his office there and lived there, the doctor monitored his health, and I observed the behavior of the designer, his employees, and his visitors (including myself). In addition, oxygen and carbon dioxide measurements were taken longitudinally under different weather conditions. A report on this experiment has appeared (Logid 1981). On the basis of the result, the team is suggesting a combination glass-and-stone house with a 50% surface for plants as an alternative

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architectural solution in the face of fading oil resources (the sunheat caught in the glasshouse can be stored), in the face of air pollution (the oxygen content in the glasshouse is, due to the plants, above the normal level of any room with open windows), and in the face of decreasing environmental quality in our cities. In contrast, the quality of life in this environment is rated very highly by the participants in this experiment (due to the colors of blossoms and leaves, the smells, and the constant change of space resulting from plant growth and seasonal cycles). This advantage must be paid for by way of an average of one hour per day spent on plant care.

I had, however, one problem with the experiment that I could not resolve at the beginning — the problem of its semiotic interpretation. For quite some time I thought that the semiotic content of this enterprise was negative only. This island of green represented, in my estimation, an escape from daily routine with its signs of human communication in bureaucracy and mass media. Plants, unlike letters, punched cards, and tapes, are not malleable. One cannot do with them as one pleases. They require care and grow according to their own plan.

Problem relevance and the semiotic approach There is little doubt that the problem of new alternative forms of working and living is highly relevant if one considers the crises of energy, environmental pollution, and the general loss of quality in daily life. This is at least true in western industrialized countries, where we witness mass tourism, suburban sprawl, and growing so-called 'green' political movements. A project like the one described above seems to give a direct and practical answer to the problems mentioned. There seems to be little room for theoretical questions of semiotics. But the lack of a theory to back up a practice has always made me suspicious. I also find the escapist tendencies in mass tourism, urban sprawl, and 'green' politics unsatisfactory. I therefore began to amplify my semiotic interests by searching for a solution to my 'cognitive dissonance'.

Jakob von Uexküll's biosemiotics I had read Jakob von Uexküll's ([1940] 1970) 'Bedeutungslehre' (theory of meaning) a long time ago.[1] I had discussed the semiotic importance of the work of this unorthodox German biologist, forerunner of ethology, many times with his son, Thure von Uexküll, who is attempting to develop further the semiotic aspects of his father's work with 'biology as a science of meaning in nature'. These discussions were often very heated and controversial because I could not cope with what I thought to be a hermeneutic approach to natural science. It took the publication of Jakob von Uexküll's selected writings

by his son (Thure von Uexküll 1980), and a careful rereading of the 'Bedeutungslehre', to convince me that a basis for a semiotics of plants could be found in Jakob von Uexküll's work. The basic premises of Jakob von Uexküll's theory of meaning in nature may be summarized as follows:
(1) Living beings, from the cell to the most complex organism, are 'autonomous'. They do not react in a causal and mechanical way to impingements of objects or other living beings as material objects do. Living beings react in a way that is meaningful in terms of their own needs, i.e., they process information according to their specific receptors, nervous systems, and effectors and according to their own code. Therefore, biology can utilize causal and mechanical explanations only to a very limited degree. The main task of the biologist is to reconstruct the meaning of a living being's behavior. This implies finding out exactly which sign processes underly behavior. In other words, biology is biosemiotics (a term not used by Jakob von Uexküll).
(2) There is a structural correspondence between each living being as an autonomous subject and its own 'Umwelt'. The term 'Umwelt' is difficult to translate into English. It means the subjective world of what is meaningful impingement for the living being in terms of its own information processing equipment, sign systems, and codes. Since 'Umwelt' is not to be confused with 'environment', the original term will be maintained. The structure of connection between a living being and its 'Umwelt' is mediated by sign processes.
(3) There is a meaningful structural correspondence between the Umwelts of different living beings within a species and those of living beings of different species, according to a 'general plan of nature'.
(4) The ultimate task of the biologist is to reconstruct piece by piece, in keeping with, and on the basis of, experimental evidence, the hypothesized general plan of nature.

Jakob von Uexküll's anthroposemiotics and zoosemiotics In order to describe in somewhat more detail the biosemiotic theory of Jakob von Uexküll, one must start with his anthroposemiotics. While this term, again, is not used by him, the meaning of the relationship between each human subject and his Umwelt, as well as the meaningful correlation between the Umwelts of different human beings, is of special importance in Jakob von Uexküll's biosemiotics. He gives many examples as evidence of different kinds of Umwelts.

One example is a walk through a town. The tailor's shop contains the concave counterforms of human bodies specialized for different activities in their lives. The clocks in the watchmaker's shop have replaced — according to abstract human time measures — the natural one of the sun, which used to regulate human lives by the presence or absence of its light. The book shop contains messages between cardboard covers that are of great importance for communication from human Umwelt to human Umwelt. The butcher's shop contains the carcasses of animals, each of which was, at one time, an organism with an Umwelt of its own, etc. Everything witnessed during a walk through town is geared to human needs. The height of the buildings and of doors and windows is related to the size of the human body. Stairs accommodate ascending legs, bannisters the arms. Each object is given its form and its meaning by some function of human life. In every case, some human affordance is backed up by a counteraffordance of an object. In fact, the meaning of an object to human lives literally consists of its counteraffordance to human affordance.

But the key role of anthroposemiotics in Jakob von Uexküll's conception arises from the fact that the scientist himself, the biologist, is a human subject surrounded by his Umwelt as if by a transparent bubble, on the surface of which appear his scientific observations in keeping with his own sign systems and codes. Jakob von Uexküll likes to quote, in this respect, the British astronomer and physicist Sir Arthur Stanley Eddington, who said he had two desks, the one he used for writing on, and the other a physical desk consisting of an immeasurably large number of particles (Jakob von Uexküll [1940] 1970). For that matter, a biologist would investigate a different desk than a physicist (Jakob von Uexküll 1935). Therefore, the scientific and especially the biosemiotic investigator must use a special method in order to arrive at a careful reconstruction of the Umwelt of the observed living being in his own Umwelt and on his own terms — a method that would now be called participant observation.

The structural correspondence between each living human organism and its Umwelt is described by Jakob von Uexküll as a 'function cycle'. The subject literally 'grasps' an object, in a double-pronged attack, either directly with his receptors (e.g., eyes) and effectors (e.g., hands), or indirectly with amplifications of his receptors (e.g., microscope) and his effectors (e.g., a tool or a machine). There is a constant feedback of signals from the effectors to the receptors, which is modified by the encounter with the object. The nervous system within the organism mediates between receptors and effectors according to the needs of that organism (e.g., hunger, defense, sexual drive, and the medium in which it lives).

According to Jakob von Uexküll, the receptors receive afferent signals from the object and the effectors are steered by efferent signals to carry out an action upon the object. Both kinds of signals are charged with meaning by the code constituted by the subject's needs. An object may thus be sensed differently and acted upon differently, depending on the actual need. The two faces of the object as a sign are the afferent signals as the signifier, and the induced efferent signals as the signified. The semiosis proceeds on the basis that the afferent signals are constantly cancelled by the efferent signals, either in terms of the consumption of the object, or in terms of a different 'perspective', or in terms of a code-switching to another need. The sum of the object signals received and their corresponding action signals constitutes the Umwelt of the organism, which is mirrored by signs as an 'inner' counterworld.

The task of the biologist is to study the code according to which a living being, be it human or animal, imparts meaning to its Umwelt, by studying the physical structure of receptors and effectors and by observing, through experimental variation, which signals are processed on each side, i.e., which signs are in the code of the living subject. The study of the Umwelt of human beings is thus, clearly, anthroposemiotic.

The role played by those particular objects in the Umwelt of human beings that are called signs has been studied by Thure von Uexküll (1980). The specific characteristic of the human Umwelt is that it is structured according to the species' framework of space and time; that, by reafferent feedback processes, the phenomenon of 'consciousness' (or self-awareness) exists; and that by transmission of sign-objects, particularly of linguistic signs, a common social reality is established.

Following the suggestion of Marx ([1857] 1961: 636) that it is scientifically more correct to explain apes by using knowledge about men than to explain men in terms of apes, the zoosemiotics of Jakob von Uexküll can now be sketched 'by subtraction'.

Returning to the example of Eddington's desk, this object becomes, in the Umwelt of a fly, a mere horizontal walking surface and is, in that respect, no different from the seat of the chair or the top of a cupboard. In fact, all objects in a human room are reduced, in the Umwelt of a fly, to objects to walk on, objects to feed on, and objects, a lamp for instance, to fly around in a kind of play activity. As Jakob von Uexküll cogently observes, the number of objects pertaining to the Umwelt of an animal corresponds exactly to the number of actions executed by it. But each animal, be it an amoeba, a fly, or a lion, behaves meaningfully on the basis of sign processes with a functional cycle forming signs from afferent signals as signifiers and corresponding efferent signals as signifieds.

The phytosemiotic hypothesis

It is the hypothesis of this study that, while plants are autonomous living beings (in the sense of Jakob von Uexküll), their semiosis is different from that of human and animal subjects in such a way that it merits its own semiotic analysis. This semiotic analysis may well form the positive scientific basis lacking so far in the conservationist activities that have, until now, largely been based on negation and ideology. The method by which the specificity of plant semiosis can be shown is that of opposition, well known in semiotic inquiry. It would thus be necessary to show by which distinctive features phytosemiotic processes differ from anthropo- and zoosemiotic processes, and at the same time, what their common biosemiotic basis is.

Phytosemiotics

Distinctive features of phytosemiotics

Fixation versus mobility Jakob von Uexküll (1922) characterizes the most obvious difference between animals and plants as that of movement and quietness:

> The confusing aspect offered by the thousands of animal worlds is due to the impossibility of finding a moment of rest anywhere. Everything is constantly in the process of breathtaking movement. ... Again and again the animal must exercise its organs to respond to the requirements of the Umwelt. Sometimes the animal is the persecutor and sometimes the persecuted. But it is always active and thus burns the materials which its digestive cells have extracted in painstaking labor from the nourishment which it has acquired in such a hard way.
>
> The aspect of the reign of plants is quite different. Hectic haste is replaced by comfortable calm. Not that work ceases for a moment, as long as the plant is alive. An uninterrupted stream of liquids enters by the roots, rising along the stem and branches out in all directions to the leaves where it evaporates again in a well-controlled fashion. This stream transports the nourishing salts gained from the earth into all those tissues of the plant which transform them into material of the plant's body. In the laboratory of the leafgreen, the important building block of carbon is produced with the help of the sun. Everything is handled by the fine detail work of living cells which remain autonomous subjects as do those in the bodies of animals. They work in union, according to a plan, by transmitting stimuli and material.

This quotation certainly should not be misunderstood in the sense that plants do not move. There is, for one thing, the phenomenon of phototropism (e.g., Presti et al. 1977), implying relatively slow movement of plants toward light sources. And there is, of course, very visible adaptive movement of plants in response to the pressure of air (wind) or water (stream).

Absence of effectors and receptors The 'comfortable calm' of the reign of plants is due to the fact that plants have no specific effector organs — no feet to run with, no arms to gesticulate with, etc. — and, correspondingly, no specific receptor organs — no eyes to look around with, no ears to hear with, etc. Consequently, there is no nervous system mediating between effectors and receptors.

This assertion appears to be in contradiction to an increasing — and quite 'fashionable' — body of literature concerned with 'plant receptors'. For instance, so-called photoreceptors have been studied in different strains of Phycomyces, a species of fungus (Delbrück et al. 1977; Delbrück et al. 1976; Presti et al. 1977). It was found, in one study, that 'the Phycomyces sporangiophore is a single cell and responds phototropically, adapting to various light levels.... The authors have analyzed the kinetics of this adaptation, using a tracking machine for greater precision. Dark adaptation is exponential ... i.e. the threshold falls exponentially in the dark, in contrast to scotopic vision where the logarithm of threshold falls exponentially in the dark.' In the other studies, the chemical functioning of these photoreceptors was analyzed, with the result that 'the bluelight receptor' of Phycomyces is not carotene (as in animals), but riboflavin.

A similar topic in the literature is the search for a functional 'plant hormone receptor' (e.g., Dodds and Hall 1980, a review on the problem with a bibliography of 65 titles). Animal hormone receptors are defined as follows:

> Animal hormones are synthesized in clearly defined organs and are then translocated to equally clearly defined 'target' tissues organs ... where they control specific biochemical processes ... the sites with which they interact must have a very high affinity for the hormone. Equally, the sites must show very high specificity for the hormone. These sites, or rather the whole molecule of which they are part, are termed 'hormone receptors'. All such receptors which have been isolated so far have proved to be proteins.

In contrast to a large number of hormones found in animals (more than 40 have by now been identified), only five groups of plant hormones are known so far. These plant hormones have a much simpler structure than animal hormones. According to Dodds and Hall (1980), 'The very term hormone is called into question in plants since the site of synthesis is not usually restricted to a specialized organ or tissue ... most if not all plant cells have had the capacity for hormone synthesis at some time in their development and many retain this capacity, even if to a limited extent.' In addition, 'there is usually no one distinct target for a given hormone since at any one time many different tissues and organs in the plant are capable of responding to it — often in a different way'. Obviously, it is this 'totipotency of plant cells', a principle formulated already by Haberland in 1902 (Haberland 1902), that differentiates so-called photo- and hormone-receptors of plants from those in animals. This does not mean that there is no 'differentiation', e.g., 'division of labor', between plant cells during the development of plants.

It is typical for the modern conception of 'plant receptors' in botany to refer to chemical 'binding' processes that are treated, according to information theory, as processes between chemical 'messengers' and 'target substances', rather than referring to specialized cell compounds or receptor organs as these are present in animals. Moreover, the useful distinction between 'exteroceptors' (e.g., photoreceptors) and 'interoceptors' (e.g., hormone receptors) is neglected by botanical terminology. I would, therefore, like to maintain Jakob von Uexküll's conception denying plants the capacity of specialized receptor organs, and rather apply to what are called receptors in the above cited literature the term 'sensors', according to the parlance of cybernetics with respect to feedback cycles.

Absence of the functional cycle For the same terminological reason, I would agree with Jakob von Uexküll in maintaining that plants do not have a 'functional cycle' connecting receptor organs via a nervous system to effector organs. What plants have is a feedback cycle between sensors and regulators. In the absence of a functional cycle in plants, there is no way by which afferent signals can be fitted together with efferent signals to form the signifiers and signifieds of 'objects'.

Casing versus Umwelt Given the absence of a functional cycle, plants cannot have an Umwelt. As Jakob von Uexküll ([1940] 1970) points out: 'The plant does not possess Umwelt-organs, it is directly immersed into its habitat. The relationships of the plant to its habitat are quite different from those of the animal to its Umwelt.' While humans and animals each have their own Umwelt, plants are confined to their casing.

Meaning factor versus meaning carrier Due to the absence of effectors, nervous system, and receptors and the consequent lack of the functional cycle and the resulting Umwelt, plants have no objects that may become the sources or 'carriers' of meaning for them. Meaning is mediated for plants by what Jakob von Uexküll calls 'meaning factors'. Meaning factors are those stimuli among the stream of impingements pressing upon the plants from all sides that are relevant to their life. The plant does not counter external impingements with the double-pronged operation of receptors and effectors, but uses the living sheet of cells of its casing to filter out relevant impingements. These relevant impingements are the meaning factors, i.e., the semiotic factors, for the living plant.

Using the example of the leaves of an oak tree, Jakob von Uexküll shows how phytosemiosis functions. One of the meaning factors, as far as oak leaves are concerned, is the rain. Falling raindrops follow precise physical laws governing the behavior of liquids upon striking a leaf. In this case, according to Jakob von Uexküll, the leaf is the 'receiver of meaning', coupled with the meaning factor 'rain' by a 'meaning rule'. The form of the leaves is such that it accommodates the physical laws governing the behavior of liquids. The leaves work together by forming cascades in all directions in order to distribute the rain water on the ground for optimal use by the roots. To put it in more common semiotic terminology, the leaf's form is the signifier and the physical behavior of a raindrop is the signified. The code coupling leaf and raindrop is the oak tree's need of liquid for the transport of nourishing salts into its cells.

Utilization of meaning by form versus utilization of meaning by function cycle The difference between plant and animal is that the plant utilizes meaning by means of its form built up according to a 'plan of nature', enabling the leaf to fit into the physical behavior of liquids, while humans and animals utilize meaning through their function cycle. The code of a plant's need is a superordinate rule coupling two subordinate rules, the physical laws governing the forming and flowing of drops and the biological formation rules according to which the leaves of a particular species of plants grow in its typical habitat. The code of an animal's need couples relevant objects or animals to the receptors and effectors of the receiving animal. The superordinate rule of the living being's needs may be considered a code to which subordinate rules relate as subcodes.

Predominance of indexicality versus iconicity and symbolicity The classical trichotomy of possible relationships between the material aspect of the sign and the object it stands for is, in Peirce, reflected by degrees of iconicity, indexicality, and symbolicity (and in the Saussurean tradition by degrees of motivation, indexicality, and arbitrariness). If one wants to extend this trichotomy to plants on the one hand, versus animals and humans on the other, the absence of the function cycle would suggest that, in plants, indexicality certainly predominates over iconicity. In animals, however, iconicity seems to predominate over symbolicity, since the double-pronged action of receptors and effectors models the object almost as a concave negative image of the two actions. Finally, symbolicity predominates over iconicity in humans because of their widespread social use of language and other arbitrary sign systems.

There are three levels of meaningful cycles corresponding to predominance of indexicality, iconicity, and symbolicity, each higher process including also the lower. Indexicality, on the vegetative level, corresponds to the sensing and regulating, in a feedback cycle, of meaningful stimulation directly contiguous to the form of the plant. Iconicity, on the animal level, is produced by the function cycle, with receptor and effector activity representing, in a nervous system, the 'image' of objects. Symbolicity, on the human level, is produced by perception and action in human society.

Communalities between phytosemiosis and zoosemiosis

Selection of impingements While there are distinct differences between the sign processes in plants and animals or humans, there are also important communalities among them. One is that they all filter out a specific selection of all those impingements surrounding them. As living beings, they are all capable of drawing a borderline between 'self' and 'nonself', utilizing only those impingements that are meaningful to their needs.

Suffering the imposition of meaning Plants, animals, and humans not only utilize impingements meaningfully, but also suffer the imposition of meaning. Jakob von Uexküll ([1940] 1970) shows this with the example of the different roles a wild flower in a meadow may play as a meaningful object in different function cycles: It may be picked by a human for a bouquet of flowers, it is utilized as a walkway and plant-louse farm by ants, the larva of the cicada may bore its nest into its stem, and the cow may eat it together with a bunch of grass. Suffering the imposition of meaning is analogously applicable to animals and humans, as is proved by the roles of prey and predator between animals and between animals and humans, and by the suppression of humans by humans. In the 'plan of nature', the meaning of suffering the imposition of meaning may range from the reduction of excess individuals in the interest of their own species to reduction in the interest of a whole ecological system, whereas social oppression among humans seems to be dictated by historical and dialectical laws.

Rules of correspondence between the Umwelts of humans, animals, and plants — the method of 'counterpoint' With the example of oak leaf and raindrop, it was shown that meaning in nature is based on rules of correspondence bracketing subordinate formation rules and physical rules. The favorite example of Jakob von Uexküll for explaining the lawfulness of these meaningful correspondences or — as one would say in semiotics — codes is that of a musical composition of which 'nature' is the composer. This whole composition, of which the biologist tries to write the score, i.e., to study the syntagmatic rules, is based on the technique of counterpoint. The method is to find the counterpoint to each note of the composition by following the motto: Wherever there is a point, its corresponding counterpoint can be found. The physical behavior of raindrops is the counterpoint corresponding to the point of the leaf's form, the soft skin of mammals corresponds to the tick's bite, the path corresponds to man's feet, nourishment to his mouth, an enemy to his weapon, as Jakob von Uexküll has pointed out.

There is one fundamental rule of correspondence between humans and animals on the one hand and plants on the other, this being of critical importance for life: Plants produce the oxygen all humans and animals breathe. In other words, the life of plants corresponds as a counterpoint to the breathing lungs of humans and animals as a point. As Jakob von Uexküll ([1940] 1970) paraphrased Goethe's verse

Wär' nicht das Auge sonnenhaft
die Sonne könnt' es nie erblicken.

by postulating

Wär' nicht die Sonne augenhaft
an keinem Himmel könnte sie erstrahlen.

we might say

Wär' nicht die Lunge pflanzenhaft
das Atmen könnte nicht gelingen.

and

Wär' nicht die Pflanze lungenhaft
gäb's keinen Atemzug auf Erden.

Measurements of oxygen and carbon dioxide The oxygen content in the air we breathe is produced by seaweed and plants. This oxygen content is, on the whole, relatively constant. But locally it might very well go down to a dangerous level. The increasing mass of fossil energy burned by vehicles and heating systems diminishes the oxygen content in our cities to an extent that has never occurred before. Escaping gases engender a serious reduction in the oxygen content of the working environment. As a normal level of oxygen concentration for places of work, 20.8–20.9% is acceptable. A concentration below 15% constitutes a health hazard. Below 10%, human life is acutely endangered. These values indicate that a symbiosis between humans and plants under a common roof should turn out to be very healthy. Schoknecht et al. (1980) tested the hypothesis that rooms containing many plants (such as greenhouses) should contain at times higher oxygen levels than outside air. Moreover, they tried to gain insight into the relationship between plant activity, measured by oxygen production, and weather conditions. Over a period of three weeks they measured the oxygen content in the greenhouse mentioned above and, as a control, in a garden and a normal living room next to the garden with an opened tipping window. The results, standardized for a temperature span of 10–40 degrees centigrade and humidity fluctuations between 30 and 80 percent, are shown in Figures 1–3.

Figure 1 represents an average daily profile of oxygen content in the greenhouse, compounded over three-hour periods (with the corresponding standard deviations). It also shows an impressive range of measurements, from a minimum of 18.74% between 6 and 9 o'clock in the morning to a maximum of 20.87% between 3 and 6 o'clock in the afternoon. During the night, the oxygen content in the greenhouse decreases because plants not only cease to produce oxygen, but also consume it. It is interesting to see

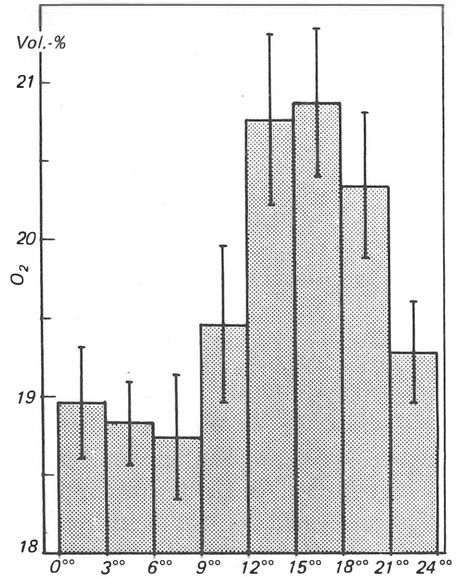

Figure 1. *Average daily profile and standard deviations of oxygen concentration in the greenhouse*

from Figure 1 that plants apparently do not start photosynthesis in a mechanical fashion with the onset of sunrise, but seem to need a sort of 'warm-up' period. Likewise, they seem not to cease producing oxygen at the moment of sundown. In any event, the oxygen content in the greenhouse does not diminish immediately after sunset. The highest concentration of oxygen (more than 20%) prevails between noon and 9 o'clock in the evening.

The profile of mean values in Figure 1 is synthesized from data measured during different weather conditions. It is to be expected that with the sky covered by clouds, less sunlight is available for photosynthesis, and therefore less oxygen is produced than with a clear sky, when sunlight can be used to a maximum degree by the plants. Schoknecht et al. (1980) took account of this by assuming four weather levels:

(1) less than 1 hour of sunshine per day
(2) 1–4 hours of sunshine per day
(3) 4–9 hours of sunshine per day
(4) more than 9 hours of sunshine per day

Figure 2 shows the curves of oxygen content in the greenhouse under these four weather conditions. The influence of the amount of sunshine

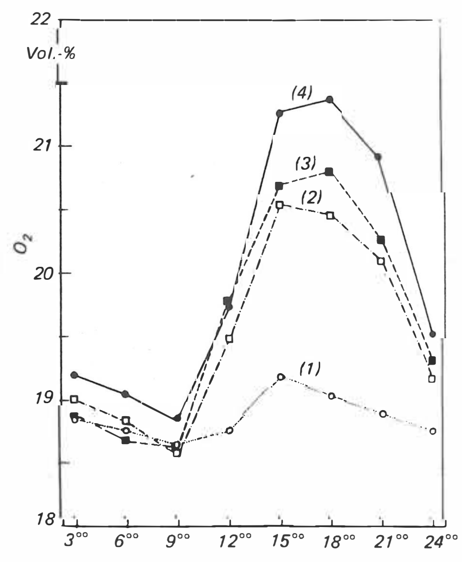

Figure 2. *Average daily profile of oxygen concentration in the greenhouse under four different weather conditions*

per day on oxygen production is well demonstrated. The profile of the mean values in Figure 1 corresponds, approximately, to four hours of sunshine per day. These measurements, however, only become meaningful when they are compared with the oxygen concentration in a normal room (1) and in a garden (2). These control measurements were obtained under optimal sunshine conditions and are shown in Figure 3. A comparison between the values obtained in the greenhouse under different weather conditions in Figure 2 and the control data in Figure 3 shows that the oxygen content in the greenhouse is like that of a normal room (with opened tipping window) only on days with less than one hour of sunshine. The oxygen concentration in the greenhouse is much higher than that in a normal room if there is more than one hour of sunshine per day. With a clear sky, it even seems to retain its peak longer than in a garden under the same conditions!

From Figures 1 and 2 it can equally be seen that even during cessation of oxygen production at night, the level of oxygen never falls to 15%, which is hazardous to health. On the contrary, air in rooms full of plants always seems to be better than in rooms without plants.

The above data are interestingly complemented by the measurements of carbon dioxide made on four different days by Drysch (1980) in the same greenhouse. The four resulting curves are given in Figure 4, from which it

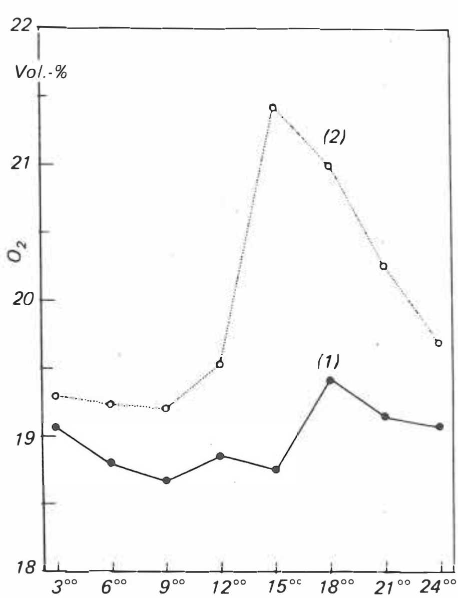

Figure 3. *Average daily profile of oxygen concentration in a living room (1) of 14 m² with open tipped window and in a nearby garden with many plants (2)*

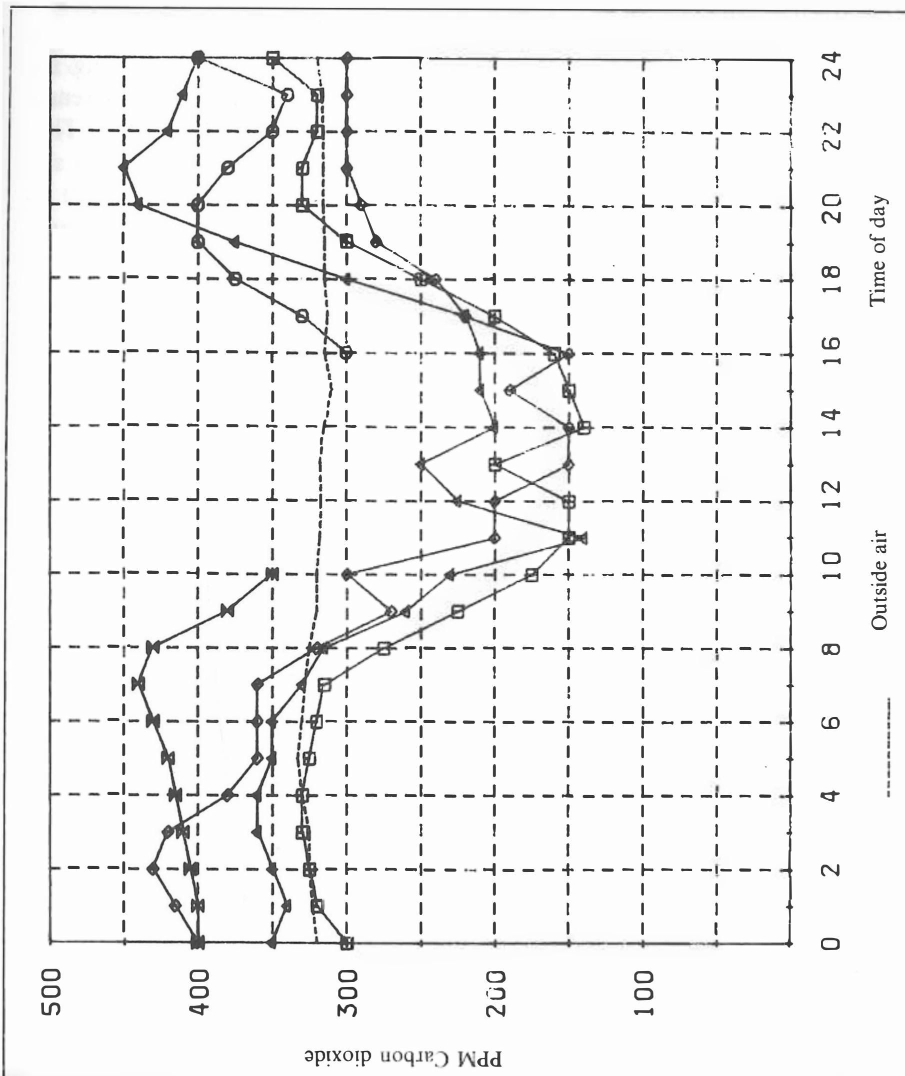

Figure 4. *Graph of carbon dioxide concentration in the greenhouse measured on four different days*

can be seen that on one of these days no measurements were obtained between 10 a.m. and 4 p.m., since the fall in carbon dioxide concentration is, from a medical point of view, not interesting. All curves in Figure 4 show a profile that is reciprocal to that of the oxygen measurements: With the rise in oxygen content carbon dioxide content falls and vice versa. The maximum carbon dioxide content was measured between 8 p.m. and 8 a.m. The norm of 500 PPM carbon dioxide concentration, inadmissible for places of work, is never reached in the greenhouse (cf. Figure 5).

The consequences of these oxygen and carbon dioxide measurements for healthy working and living conditions are obvious. According to medical experts, there seems to be a clear correlation between the increase of cancer and diminishing oxygen concentration in industrial areas. The

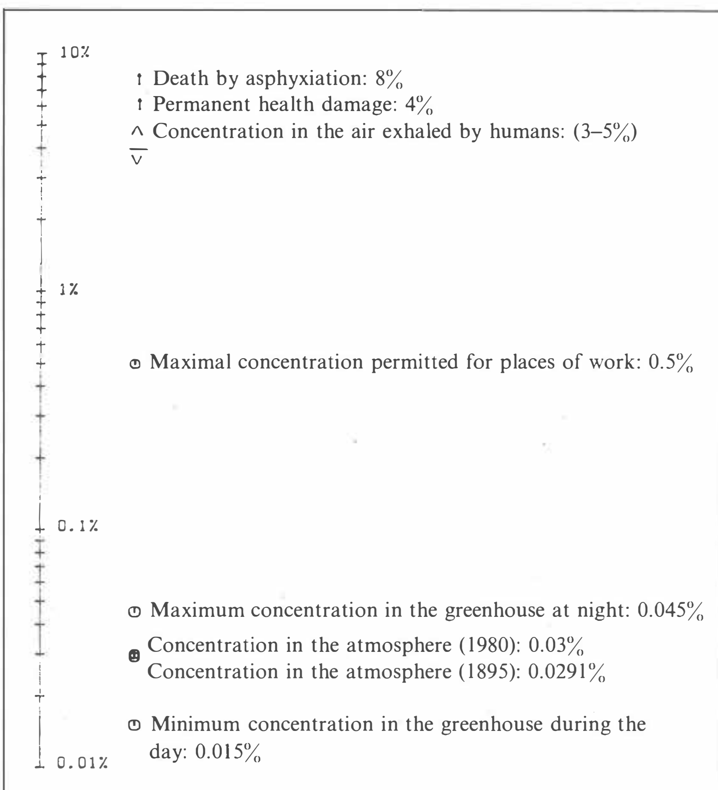

Figure 5. *Physiologically retevant span of concentration of carbon dioxide*

data are presented here to demonstrate the meaning of plants to human life and to point out the necessity for further investigation in phytosemiotics.

Three forms of life and their common semiotic aspect It has been shown above that the semiotics of the vegetative world is different from that of animals and humans, in that the absence of effectors and receptors does not allow for the constitution of a functional cycle, of object signs and sign objects, or of an Umwelt. The vegetative world is nevertheless structured according to a base semiotics which cuts across all living beings, plants, animals, and humans alike.

As Thomas A. Sebeok and Thure von Uexküll have pointed out, many life processes within the animal and human organisms function according to the principle of the vegetative world, i.e., according to the principle of phytosemiotics. This field of semiotic inquiry has been labeled endosemiotics by them (Sebeok 1976, Thure von Uexküll 1980). As soon as a functional cycle is constituted by the presence of effectors and receptors, through the mediation of a 'vegetative' nervous system, the phenomenon of Umwelt arises in animals and humans alike. The semiotic aspects of the Umwelt have been called 'exosemiotics' (Thure von Uexküll 1980). Whereas endosemiotics is pertinent to all three forms of life, plants, animals, and humans, and thus pertinent to phytosemiotics, zoosemiotics, and anthroposemiotics, exosemiotics is pertinent to zoosemiotics and anthroposemiotics only. As Thure von Uexküll (1980) suggests, the age-old problem of the dualism of body and soul might thus find a biosemiotic answer. Plants would therefore exhibit predominantly indexical sign systems; in animals, both indexical and iconic signs would appear; whereas human sign processes would display the whole range of the trichotomy, from indexicality via iconicity to symbolicity.

Meaningful interactions between plants and animals Thus far, only differences and communalities between the sign processes in plants, animals, and humans have been accounted for. Some examples of semiotic interactions between these living beings will now be presented.

It is well known that plants have chemical defenses against the attacks of herbivore animals such as insects. There are two classes of such defenses. Either chemical deterrents are already present before the attack occurs or such a deterrent is mobilized in response to such an attack. The latter defense is known as 'induced resistance'. It is practiced frequently in higher plants against infections by microorganisms. Induced resistance sometimes occurs, however, as a counterattack by the plant against the attack of an herbivore insect enemy. As far as this insect-induced resistance in plants is concerned, it is interesting to study the time plants need for mobilization. Most of the observed cases of this type of resistance have long response times, ranging from 12 hours to as much as several years. But there are examples of relatively rapidly induced resistance. I am grateful to Thomas A. Sebeok for drawing my attention to such an example published recently (Carroll and Hoffman 1980). It shows a complex sequence of animal attack on the plant, rapid counterattack by the plant, and adaptive countermeasures against this defense of the plant on the part of the animal. The crookneck squash is attacked by a beetle species labeled *Epilachna tredicimnotata* (Coleoptera: Coccinelidae). This bug first uses its specially formed apical teeth to cut a circular trench in the crookneck squash leaf and then feeds only on the cut-out disk. The trenching takes about ten minutes, obviously time enough to isolate a part of the leaf from the chemical deterrent that the plant mobilizes against the attack. The response time of the plant and some further circumstances connected with this interaction between 'prey' and 'predator' have been investigated experimentally by Carroll and Hoffman.

They used the circumstance that the deterrent mobilized by the crookneck squash against *Epilachna* is a feeding stimulant for another beetle (*Acalymma*). The latter refuses, for instance, to feed on crookneck squash leaves that have been recently removed from the plant and, therefore, cannot yet have been reached by the deterrent (unless it has been locally synthesized). The response time of *Epilachna* attacks on the crookneck squash can now be experimentally 'chronometrized' by damaging crookneck squash leaves and varying the time between damaging and cutting a part of the leaf as food for the two kinds of beetles. The first kind should refuse, the second kind start feeding from the moment at which the deterrent has arrived at the damaged area of the leaf. Carroll and Hoffman found that it takes the crookneck squash about 40 minutes to mobilize the deterrent and to send it to the attacked area. *Epilachna* is faster, however, and takes only ten minutes to cut out an area from the leaf before the deterrent can reach it! (Or is it content to eat only what it can cut out in 10 minutes, the plant, in turn, tolerating this minor damage?) After reviewing some similar cases of plant–animal interaction reported in the literature, Carroll and Hoffman suggest that the fact that herbivores often move from one plant to another before having finished feeding might be an adaptive response geared to avoiding the arrival of defensive deterrents at the feeding point.

Meaningful interactions between plants and men: (1) The 'green thumb' theory As far as the interaction between humans and plants is concerned, there is a widespread popular conviction that some people have 'green thumbs': Whatever seed they put into the earth will grow and mature nicely. Others, not gifted with this magic capacity, can do whatever they like — the plants will die for them. I have heard people explain this phenomenon by the alleged radiation of an aura that is particularly 'congenial' to plants. But even admitting that living beings possess their own 'aura' of radiation (for instance, warm-blooded animals radiate heat), I would suggest that 'green thumbs' is a phenomenon analogous to that of 'clever Hans' of which Sebeok (1977, 1978) has repeatedly warned us. The 'magic', in this case, lies in the fact that some people have a different attitude towards plants, know more about them and, consequently, take better care of them. It is no wonder if plants react positively to this treatment.

(2) Caring for plants Another concept of meaningful interaction between plants and humans could be based on the differentiation of 'meaning' into two classes: There are objects that are 'indirectly' meaningful to us, such as words or other communicative signs. But there are also objects that may acquire 'direct' meaning. This is, for instance, the case with 'cherished' possessions, which may become receptacles of personal memories, e.g., a gift from a friend, or tokens of attitudinal justification, e.g., a 'status symbol' or a trophy. Plants, for instance, are generally present in the 'object ecology' of a typical middle class home and tend to carry a special meaning for one or more members of the family. Csikszentmihalyi and Rochberg-Halton (1978) and Rochberg-Halton (1979) have shown in their studies on the meaning of 'cherished household possessions' that, for children, parents, and grandparents, quite different objects acquire meaning for quite different purposes. The younger generation names, as its preferred possessions, objects that require active manipulation — e.g., stereo units, musical instruments, pets, etc. The grandparents, on the contrary, prefer objects of passive contemplation, such as family photographs, books, paintings, crockery, etc. The middle generation, the parents, take an intermediate position between their children and their own parents as far as the 'motivation' of cherished objects is concerned. Their preference ranges from paintings and books to musical instruments, plants, and stereos (in that order). The middle rank of objects for the three generations shows a decrease in life characteristics: children prefer pets, parents plants, grandparents crockery. Also, the same objects may obtain different ranks, depending on whether they are ranked according to one or another of three different meaning dimensions: first, reference to self versus reference to other; second, current experience versus memory of the past, and third, personal values. The latter dimension of meaning reflects objects as models of the self or templates of

self-development. It is in this dimension that plants, together with books, rank first, i.e., above all other objects. By analyzing the rank order of parents separately, i.e., women versus men, one finds plants only in the rank order of the former, whereas the latter have tools and trophies in their preference list as objects meaningful only to men. Obviously, in these choices, differences in the conception of self are involved that are due to stereotypes of sexual roles. As Csikszentmihalyi and Rochberg-Halton (1978: 12) put it: 'The meaning system built by men is different from that of women partly because they learn to use different things to objectify experience. The feelings and thoughts one has in caring for a plant are bound to be different from the ones a person has when using a camera . . . We are assuming that a plant produces, in its (characteristic) caretaker, feelings of nurturance while a trophy is more likely to invoke a feeling of pride in one's past accomplishment.'

This phenomenon of plants evoking the nurturance instinct in humans is nicely demonstrated in a report by Newman (1979) on a particular type of interaction with plants, exhibited by a woman who served as a subject in a study on a person's relation to objects. By eliciting accounts of this woman's most highly valued activities, Newman found that she focused her main interests on collecting, repairing, and nurturing. Her main collector items were valuable Indian prints, as well as stones she picked up. She repaired her own car and other objects around the house, being directly prompted to do so by her feminist orientation, prescribing that one has to learn to take care of oneself. The nurturing aspect of her activities was clearly visible by the mass of plants in her house. But this aspect was brought out even more by the fact that she used to go to supermarkets and plant stores every so often to buy plants that were dying. 'Then she would nurse them back to health, propagate them and give them to friends who would be good to them. Thus, she said, she "worries a lot" about them' (Newman 1979: 4a). Apparently, her interaction with plants excluded aesthetic contemplation. Caring for plants was a very active form of 'rescuing' in the woman's life.

This example shows, in a psychological way, how important plants may become for humans. The study of the psychological relationships between men and plants is still in its very early stages. One of the tasks ahead lies in the development of an attitude-toward-plants-test, which could complement other 'environmental inventories', e.g., the Environmental Response Inventory (ERI) of McKechnie (1977), already used in environmental decision making, planning, and aptitude testing.

(3) Learning from plants Plants not only evoke nurturance behavior but often become something like 'teachers' when we interact with them. The

'comfortable calm' they radiate has already been mentioned (Jakob von Uexküll 1922). But they may also become 'living examples' of 'passive resistance'. As Jakob von Uexküll ([1940] 1970) says: 'A plant solves its main task by passive surrender to the effects of the Umwelt into which it is slotted. Since the plant is not mobile, it has to face all those external effects which are present in its surroundings. The most efficient means of an animal's self-preservation — escape — is not available to the plant.' In addition, the example of the plant's life rhythm can be very instructive to humans. Some plants certainly possess, in their genotype, the capacity to predict, independently from weather conditions, the change of seasons. And Jakob von Uexküll ([1940] 1970) observes, in this respect:

> Since plants are not dead cases, but are constantly forced to defend their lives, we recognize in them a life rhythm paralleling the change of the seasons. Our deciduous trees lose their leaves in autumn and change into plants, independent of water, in order to survive the effects of dehydration imposed on them by frost and frozen ground. The inner rhythm of plants, however, is adapted even more intimately to the changes of the year because it has been shown that our fruits grow best in hot houses, if one exposes the trees to the drop in temperature normal during their blossoming period.

Finally, plants impress us not only with the biotechnical solutions they find to their problems but also with their 'wisdom' in architecture: 'The houses of men are immobile and immediately betray their locality in their external habitus: Roofs and windows must be built differently, depending on whether snow, rain, storm or heat from the sun menaces the house. Plants, likewise, demonstrate through their form whether they must defend themselves against drought or water, against an excess or a lack of light.' (Jakob von Uexküll [1940] 1970).

Generally, human aesthetic experience is heightened in symbiosis with plants, since the plant's foremost 'receiver of meaning' is its form, linked with physical 'meaning factors' that generally follow physical laws. Thus, plants not only adapt indexically to their environment but also iconically portray the forces of their environment through their meaningful form. A study of literature and poetry, of painting, religion, and other human endeavors should convince us that plants have served as meaningful signs, indexical, iconic, and symbolic, in many cultures because they are living beings possessing features that evoke the attribution of meaning to a very considerable degree.

Discussion and some conclusions

Jakob von Uexküll's approach to biology as a science of life is a holistic one: The whole is not explained by the functioning of its parts, but the meaning of the parts is explained according to the plan of the whole, a principle that is not unlike the fundamental proposition of Gestalt theory. Admittedly, with his postulate of a 'general plan of nature', one reaches the borderline of the operational. But if the 'general plan of nature' is taken as a hypothesis, guiding, step by step, the experimental verification of 'rules of correspondence', it loses its pseudoexplanatory character.

It may also become a guideline for ecological research and, indirectly, for the political conclusions based upon it. The ideological veneration of greenery and its attendant blind search for alternatives can be replaced by the detailed study of the symbiosis between humans, animals, and plants, and ecologically sound solutions to contemporary problems can be deduced from it. Despite the impression of progress raised by the constant introduction of new and sophisticated tools between human effectors or receptors and the human Umwelt, the human organism cannot escape the basic vegetative rules of endosemiotics and remains locked together with plants by a mutual rule of correspondence: If men cease to care for plants, i.e., cease to understand their meaning factors and the meaning rules at the basis of their formation rules, they will asphyxiate themselves. As Thure von Uexküll (1980) has put it: 'Man is led, from his extravagant position as the observer positioned outside nature and as its unscrupulous exploiter, back into nature, in which he must arrange himself for better or worse.' Phytosemiotics can help to improve this arrangement.

Note

1. An English translation of Jakob von Uexküll's 'Bedeutungslehre' ('The Theory of Meaning') will appear, with an Introduction by Thure von Uexküll, in *Semiotica* in 1982.

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