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The Eyes of the Olms

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ABSTRACT – The experiments of the Austrian biologist Paul Kammerer to breed eyes in blind olms is probably one of the most notable manifesations of Lamarckian thinking and research at the beginning of the 20th century. If living in the environment of the dark caves in the Slovenian Kraijna for thousands of years has reduced the eyes of the olms until they nearly disappeared, then is it possible to influence the development in the other direction and speed it up? Will a transformed milieux or media (in a Lamarckian sense) conduct olms to vision, to the mysteries of light? Kammerer's legendary skill in taking care of animals (especially amphibians), the highly modern research environment of an institution unique in whole Europe and America at that time (the *Biologische Versuchsanstalt Wien*), years of experimental crossings, and, finally, the convergence of biological media and technical media (for example media of development in photography), provided the opportunity for Kammerer to succeed. The olm experiments are part of an elaborate research program of the Viennese *Versuchsanstalt* and its facilities that assume the environment of animals to be the critical point in developmental, hereditary, and evolutionary research. Theoretically Kammerer's olms ask questions about vision in general and its organ, the eye.

KEYWORDS – Non-Darwinian biologies, inheritance of acquired characters, developmental biology, amphibia, Paul Kammerer, Vienna Biology, theory of vision, media, biological media

Introduction

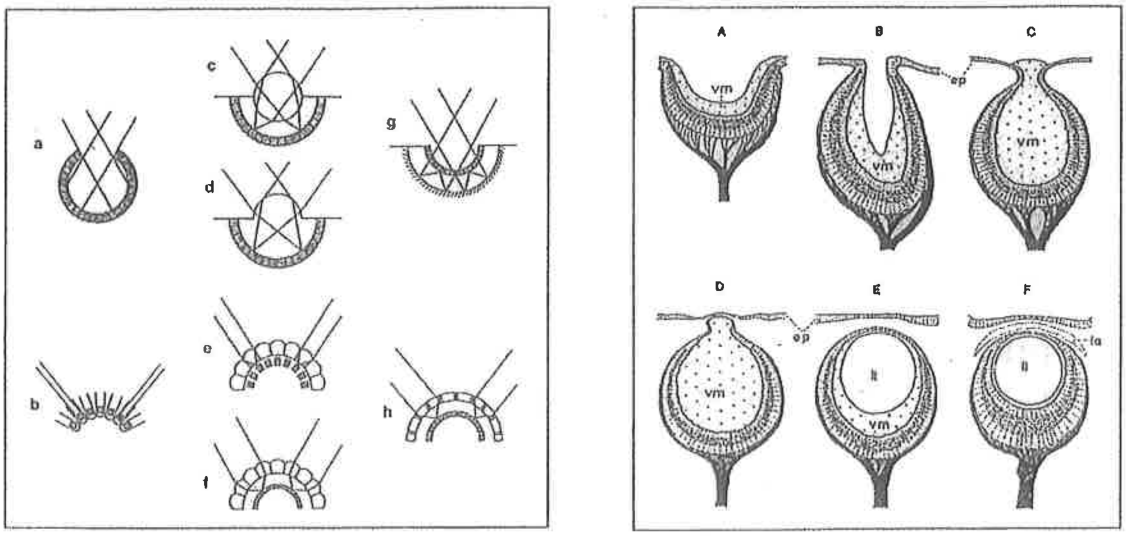
The narrative of modern, evolutionary biology begins with an almost fictive world, so temporally distant from the present that notions of any other world are bound to be destroyed. 530 million years ago, all strains of macroscopic animals which exist today had developed within a very short time, namely 5 million years. These animals are beyond the dimensions of bacteria and protozoa. To their visibility we ourselves are indebted. The so-called "Cambrian explosion" had a center: certain creatures began to devour each other, to hunt each other, and to escape from each other. This hunt has been visually guided right from the start.

This primal scene of the evolution of eyes as conveyed by evolutionary biology has a series of implications. The conditions are far from unambiguous. The hunt implies a multiplication of modes of movement. New modes of movement imply hard structures from a certain dimension onwards; i.e., external or internal skeletons. And, finally, the mobile, visually-guided hunters put an immense selective pressure upon the entire rest of the Cambrian mass. Counter-measures are put into action: hard shells, burrowing or, the best case scenario, seeing better in order to be able to run away. The consequence is some sort of "visual arms race." The visually-guided hunt may have, according to Michael Land's modern standard work on animal eyes (Land and Nilsson 2002), triggered that unrivalled evolutionary event in the development of animals. This implies that today's evolutionary biology pays homage to a remarkable, even strange ocular-centrism.

Once the primal scene of vision has been described as a hunt, then the steps in the evolution of the eyes reaches a high degree of discursive consistency. This is because the evolution of the eye can be described in engineering terms. For a hunter, vision is important only as it is related to space; i.e., spatial vision supports orientation in a given space. Or, in abstract terms, vision begins where "light from different directions is differentiated at the same time" (Land and Nilsson 2002, 5, fig. 1.4).

This can begin quite easily with two light cells whose differences are worked out in terms of neurons. However, one single light-sensitive cell is not vision and not an eye, since it is only related to light and not to space.

Figg. 1 and 2 - Different types of eyes (Land 1999, 315, Figure 2).



Seen from the notion of spatial vision, evolution faces some "problems" that need to be "solved." More precisely, it faces three problems. The first one is of image. A group of light-sensitive cells bending inwards to form a cavity will never deliver an image in the physical sense. This only happens when light rays are not spread, but are filtered through a hole, producing the camera obscura effect.[1] But when this first problem is solved, the second one follows. Once the light rays are filtered through a hole, they are very weak with a very low light intensity. "How did animals solve this problem?" (Land and Nilsson 2002, 317) They solved it by developing a lens – a glass body. However, the problem with a lens is that it is really sharp in only one level of space and delivers a blurred image in all others. This is why the evolution of lens-based eyes elaborated the modification of focus through adaptation. Given that evolution proceeds in this way right through mutation and problem-solving selective pressure, a light-sensitive piece of skin was able to develop into a lensed eye within five hundred thousand generations, in spite of Darwin's difficulties to explain the evolution of eyes (Land and Nilsson 2002, 320).

For modern evolutionary biology the development of the eye means, first, the development of the image, of a physical image, prior to any neuronal processes. This may sound strange to well-known visual science, but the moment the physical image arises in European cultural history, by means of the camera obscura, is also an event (Kittler 2002, 61-65). It would be more than just one counterpart of the camera obscura and its image brought forth by evolution. The dizzying question as to how the two "stories" relate to one another must still be developed.

The second issue, when the evolution of the eye is thought of in terms of the hunt and space, relates to the notion of functional space. The image is a physical constraint, as biologists say, and no less than the relation between dimension, weight, and surface of a creature is a fundamental starting condition for its entire construction plan. Evolution starts only when physical forces enter into a functional space. And this space finally relates back to the visually-guided hunt; in short, to the struggle of the species.

Two years after Heidegger's lecture during the winter semester of 1929 on the stone without a world (*weltloser Stein*), the animal with a poor world (*weltarmes Tier*) and the world-forming existence (*weltbildendes Dasein*), alias man (Heidegger 1983, § 42 - § 63), Oswald Spengler's Nietzschean philosophy of life gave birth to a philosophy of technology

[1] In physical terms, this is the question of the acceptance angle. For the Cambrium, Land prescribes an average of 5°, for the Drosophila in each of its vision sectors 1°, for the human eye, an acceptance angle of one minute (cf. Land and Nilsson 2002, 316).

with the hunting predator and its vision as the starting point (Spengler 1931). Herbivores differentiate themselves from carnivores through their "way of having a 'world'," as Spengler puts it, with reference to Jakob von Uexküll's "Umweltlehre."[2] This world can be discovered literally by "reading" the eyes of animals. According to the avocational biologist Spengler, herbivores – horses, giraffes, cows – have eyes that grow laterally. All animals that hunt prey, however, have eyes that are directed to the front in a parallel manner. "Focusing the eyes to the front in a parallel manner is equivalent to the *development of a world* in the sense that the human being has this world as an *image*, a world in *front of his sight*, as a world not only of light and colors, but mainly of *distance* in perspective, of *space* and the movements within it..." (Spengler 1931, 19). Spengler's view will pave the way for the slogan, "The world is prey," which has, as is well known, a steep political career in the Germany of the 1930s (Spengler 1931, 20). According to Spengler, thinking the struggle for life with all its enhancement, nobleness, great meaning, and *amor fati* in terms of hardship, distress, and angst means to arrive at Darwin's struggle of the species,[3] this foundation against which modern biology has to evaluate everything, including the evolution of the eyes and its organs.

Against this sketchy background, the following passages relate a story that continues to make a career of scandal. It is a story that is perhaps less British and less German than it is French, Austrian, or Russian. This story concerning the field of vision and its organ can be seen as the counterpart to Siegmund Exner's physiological research of the compound eye, on which Christoph Hoffmann is working.[4] (Exner's thorough study about the eye of the beetle *Lampyris noctiluca*, his experiments to operate the compound eye out of the beetles head and applicate it to the lens of a photocamera, ends with a famous photo through the window of the laboratory "as seen by a beetle" and the question of how the environment of a beetle is shaped [Exner 1875].) It is important not just because the following story is about the eye of a vertebrate, but more particularly because it begins where Exner finishes; that is, with a certain animal and its environment. It begins with "environment" in a diverse and emphatic sense. This environment – in which, according to Heidegger in his lecture a Third Reich later than the 1929 lecture,

[2] Spengler refers to von Uexkül's article "Biologische Weltanschauung" from 1913 (Spengler 1931).

[3] And, according to Spengler, to Schopenhauer (cf. Spengler 1931, 22).

[4] Cf. Hoffmann 2006. The present article is the product of a research project "Andere Augen" together with Christoph Hoffmann (Berlin) in Vienna 2006 and will be part of a book together with Christoph Hoffmann and Jan Müggenburg (Vienna), "Andere Augen. Exners Käfer - Kammerers Olme - Maturanas Frösche", coming out next year.

"all the mystery of the creature is compounded" (Heidegger 1949, 16) – this *environment* is already ahead of a poor or rich *world* of the animal and its potential construction by Uexküll, Kafka, and Heidegger.[5] It is not contemplative or literary, but practical, because environment can be manipulated. It is from here that experiments are possible. However, experiments such as manipulations in a creature's environment are not as structurally decisive as they are at the practical and operational basis of all physiological knowledge. They pull and breed and are, as such, tied to a time index, which makes them different from animal physiology.

As shown by Hoffmann, the functional turns into biology when it has to relate to a certain environment – in Exner's work as a static image or movement – whenever it meets its frontiers. According to Darwinian teaching, biological surroundings mainly consist of other animals and the resulting "tasks" for which a function is a function.[6] In contrast, the most emphatic notion of environment brought up by Lamarckian notions is different: it no longer takes turns by functions, as the environment directly affects the creatures in terms of air, heat, water, electricity, and finally, light.

Kammerer and the Olms

In September of 1897 the Kammerer family vacations on the Adriatic Sea. The young high school student Paul deserts the family and visits the famous Škocjan Caves near Trieste. He walks around the caves with a guide for two hours. Once in the main grotto, the guide shines his light into the shallow water close to the shore: "The olms were lying there." The light shining into the pools makes the olms "burrow into the clayey mud."[7] Then they are gone.

That may well have been the first encounter of the Viennese biologist Paul Kammerer with an animal that, as he will later put it, "has confronted us with the biggest problems a single species can deliver," (Kammerer 1912, 326) the famous olm, *Proteus anguinus* (Laurenti). Long considered in the local area of Krajna as a lindworm that causes great disaster, it was brought to the attention of the famous Viennese amphibian researcher Josephus Nicolaus Laurenti by farmers and the

[5] Concerning Kafka see for instance his novels about the world of a beetle (Die Verwandlung), about the world of an ape (Bericht für eine Akademie), or the world of a dog (Forschungen eines Hundes).

[6] Cf. e.g. Schlosser and Weingarten 2002 for the current discussion on the function in biology.

[7] Kammerer 1912, 326. – Kammerer will later begin here with his Lamarckian account of the olm: the "burrowing way of life" as a reason for the spatulate head which serves as a type of "drill."

canon of Gurk in 1770, who described it for the first time (Brehm 1912, 146). In the former Yugoslavia, the olm was known from elementary school books to all as a popular hero of tourism.

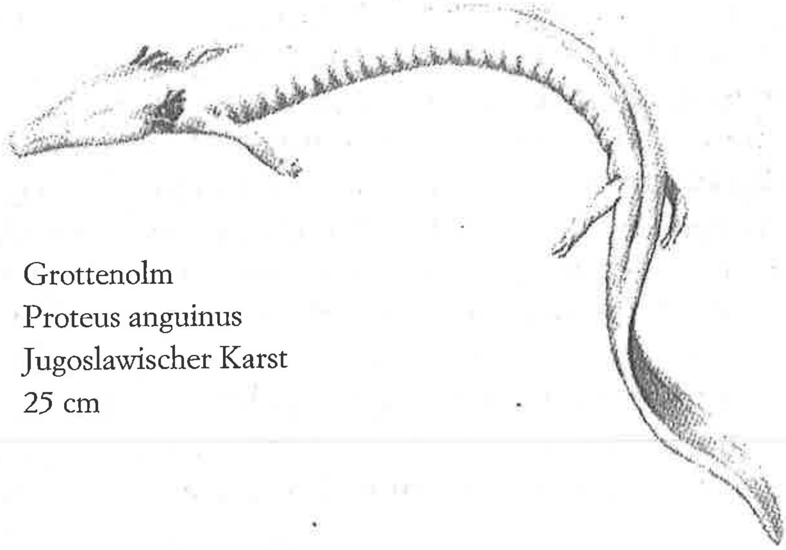


Fig. 3 - The Olm (*Proteus anguinus;* Popular textbook).

Wherever an animal is at the center of a science, this science is – without exception – based upon the novelty of an encounter. Kammerer's actual encounter with the olms will take place five years later in a different surrounding. Hired to maintain the fish tanks, Paul Kammerer is responsible for the aquariums and terrariums of the legendary *Biologische Versuchsanstalt*, called the Vivarium, in Vienna's Prater. In this context, he has taken over "40 particularly large examples" of olms from the forerunner of the Vivarium, Hagenbeck's amphibian and reptile exhibition.[8] The change of environment from the caves of the Krajna to the metropolis is, in this case, particularly fortunate. The Vivarium is equipped with the most modern, state-of-the-art environmental technology, such as automatically regulated temperature chambers for terrariums (Reiter 1994, 587 sqq.). In addition, there is also a cistern five meters deep, a sort of "subterranean hall" (Kammerer 1912, 365). It is here that the olms become familiar with their new conditions, as Kammerer reports in his long, technological maintenance account. The new environment has a constant temperature, light only once

[8] In the long history of the, "Biologische Versuchsanstalt" during some years before the foundation of the Versuchsanstalt the zoo entrepreneur Hagenbeck from Hamburg, Germany, operated a big show aquarium in the little palais near the famous Volks- or Wurstl-Prater where the Versuchsanstalt was located.

a day during maintenance and care, no soft ground of sand, but instead stone and fresh water. So nothing can obstruct biological observation, but for the olms this means the end of the "burrowing way of life."

Everything that happens in the following is basically related to environments. They are practical, i.e. driven by concerns of maintenance. The question of what animals see, of what kind of world they have, never even arises, since the question always is, what do the olms eat, what do they do, what do they want to do, how does one make them propagate, etc.? "Other worlds" are always other worlds in terms of practicality, from inhabiting the caves in the Krajna to becoming the pets in the Prater. Under Kammerer's care, known throughout the city for its genius, the olms prove to be rather flexible concerning their environment – contrary to such reports as the one by August Weismann's assistant Miss Chauvin in Freiburg, who enters the room with the olm-aquariums only on tiptoe and with a flashlight (Chauvin 1883). "I reported only three casualties in the entire span of eight years" (Kammerer 1912, 365).

Olms belong to the class of amphibians, the class of animals to which most of Kammerer's experiments are dedicated: salamanders, toads, olms.[9] Amphibians live in their environment in a manner totally different from Exner's lightning bugs, with their shell of chitin. Instead, amphibians are permeable. Their skin is naked, with big adenocytes that discharge phlegm. Some breathe through their skin. They live on the border between water and land, in direct connection to all external wetness. The skin of most amphibians is particularly sensitive to light. Heat is not generated by the organism itself but by the environment; that is, amphibians are ectothermic.

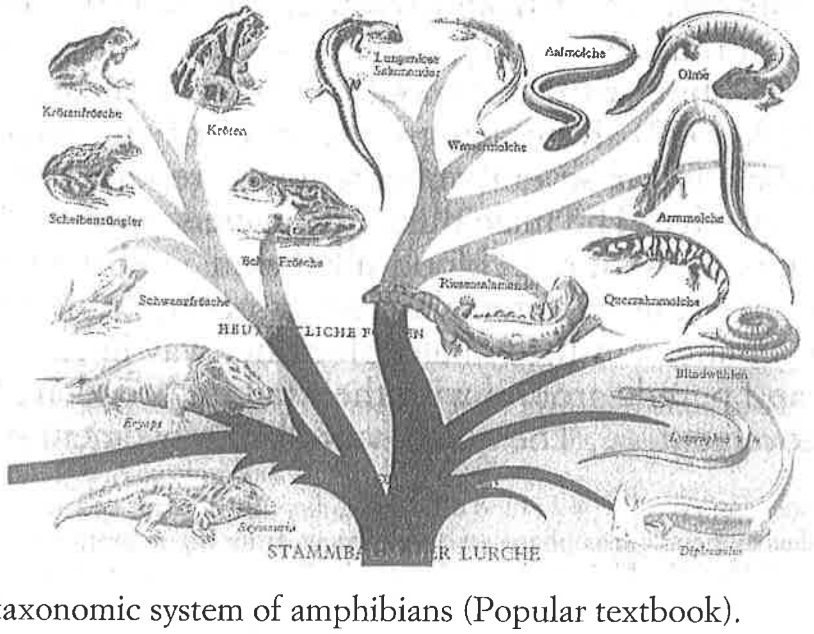


Fig. 4 - The taxonomic system of amphibians (Popular textbook).

[9] The exceptions are the *Ciona intestinalis* and later the lizards of the Dalmatian coasts.

In their ontogenesis they imitate the phylogenetic way from water to land. Most amphibians are terrestrial animals and return to the water for mating, laying eggs, and hatching. They also undergo change in the water, which makes their development and their ontogenesis a textbook case for evolutionary researchers: complete metamorphosis, from egg to larva (the tadpole in the case of the frog) to sexually mature animal. "Holometabola change," or metamorphosis, means the fundamental, organizational change in shape of a creature during the course of its development. The most famous case are butterflies and moths with their development from egg, caterpillar, cocoon, and imago.[10]

It is here, in complete metamorphosis, where the critical question of the olm *Proteus anguineus* (Laurenti) resides. There is good reason why its ability to change has been inscribed in its name going back to the *Odyssey* and the wise men of the sea of Egypt (Odyssee, song δ, verse 437 sqq.). What is so exceptional about the olm's development is that it remains on a larval level and becomes sexually mature at the same time. The dark red exterior gills are proof of this termination of development, the so-called "neoteny." The olm is a sexually mature type of larva. The olm is also not unambiguous in terms of propagation. The ambiguity of whether it lays eggs or whether it gives birth to small, three centimeter long olms is simply the beginning of its scientific career, which began with the detailed and mysterious protocol by the Slovenian farmer Stratil, who reported that he had seen how a female olm had given birth to three babies (Brehm 1912, 150 sq.).

In contrast to this, there is less doubt about the olm's love life. Miss Chauvin, the olm researcher from Freiburg, observed the long-awaited scene for the first time. According to her, the females take the initiative "by caressing (rubbing with the snout)" (Chauvin 1883, 675; also cf. Kammerer 1912a, 382). Kammerer – the lover of the famous dancer Grete Wiesenthal (and of several of her sisters) – reports that the female olms are more passive. The male olms don some sort of wedding dress during the mating season, red "blood-filled skin . . . broadening of the tail fin." First, they lionize the female, if necessary by "pinching it hard." "They like to get ahead of the female, block her way in case she tries to dodge them, and parade around with their tail fin broadened, bent and in constant movement. . . . The quick, wave-like movement of the fringe

[10] The amphibians in their earliest phases of development, from egg to morula to gastrula, belong to the founding animals of the biological science of "developmental mechanincs" for exactly this reason; this branch of biology – known as developmental biology – today leads to some discussion among Darwinian evolutionary biologists. Kammerer and other biologists of the Viennese Vivarium published most of their works in "Roux' Archiv für Entwicklungsmechanik," a type of internal bulletin of the "Wiener Versuchsanstalt."

and the slower, independent one of the tail make a beautiful picture . . . ." The problem is, olms are blind. What do they see of this beautiful picture? Kammerer offers one prosaic and one pathetic explanation. The mating dances "must either have a trigger effect for the females' sense of feel, since they produce a certain stream of water." Or the pathetic, impassioned version: they "have sunk to a meaningless ceremony, a mere reminiscence of life in the light when the female was still able to see the graceful efforts of her courter and his beauty" (Chauvin 1883, 382). Kammerer 1912a

Its life in darkness will be the mission with which the olm haunts the history of biological science since Jean-Baptiste Lamarck. Young olms have small eyes that correspond to the dimension of their bodies. During the course of their development, however, these eyes do not continue to grow. They wither, skin grows over them, and only the rudiments remain as a type of retina, without a lens. Olms are blind, since they live in darkness and they live in darkness because they are blind. Beginning with Lamarck, they have fared as examples of the regression of organs due to non-use. The regression of the eyes is a shining example of the influence of environment and living conditions on the development of organs. The seventh chapter of the first book of Lamarck's *Philosophie zoologique* turns to the mole as a prime example, then to the Egyptian-Persian "Aspalax," and finally to the "Proteus, a water reptile that is related to the salamander and lives in deep, dark, underwater caves" (Lamarck 2002 [1809/1903], vol. I, 189). It only possessed "traces of an organ for vision" because it never used it.[11] The Lamarckian use of Paul Kammerer's olm research enters here. If, according to Kammerer, the eyes of the olms "represent the paradigm of the withering of an organ due to non-use" (Kammerer 1912a, 425), then perhaps the opposite would be possible. Would eyes not regress in certain other environments but instead would grow with the entire organism?[12]

Kammerer's eye experiments start at this point. They begin on 18 May 1906[13] and last five years, until April 1911. This is a long time for physical experiments but seen from an evolutionary angle and from hundreds of thousands of generations, it is a short time, even a very rapid one. The

[11] According to Lamarck, regression of the eyes takes place in contrast to the development of the ear. "Sound material," as Lamarck calls it, is everywhere, it fills everything; not so with light (cf. e.g. Kammerer 1912b, 190 and comment).

[12] Kammerer does not accept authorship of such a bold idea: "This thought and the decision to try the respective experiment does not come from me but from the private docent Dr. Hans Przibram, since I would have considered all this as hopeless" (Kammerer 1912a, 428). Przibram, the founder and director of the Vivarium, comes from an influential Viennese family of physicists.

[13] Given the date of today's lecture, May 8, 2006, in ten days the experiments will have started a hundred years ago. This could also be an anniversary for the year 2006, to be celebrated between Mozart and Freud.

period of physiology and physics and the period of evolution define two different orders of knowledge.

First, a brief sketch of the course of interesting experiments in terms of their history.[14] From the 40 olms in the cistern of the Vivarium, including those inherited from Hagenbeck, nine olms are taken and exposed to light, the "light olms" or "experiment olms." Nine other olms remain in darkness under the same circumstances, the "dark olms" or "control olms." The rest of the olms remain in the cistern, for breeding and a reserve for further experiments. A fundamental difficulty arises shortly after the start of the research program. Each of the nine light olms behaves slightly different from the others. The control olms all behave the same, the experimental olms all behave differently. One exhibits glass-like circles in the eye area; another shows a bulge in the eye area that suddenly regresses, etc. Variation, the motor of evolution for Darwin, becomes an experimental blockade. The variation has a deeper cause, according to Kammerer. Changes in physiological processes or instinctive expression, even the modification of color in salamanders (Kammerer 1912a, 429; Kammerer 1912b), are harmless in contrast to the fundamental procedure of the growth of an organ. Even small differences in the "constitution of the animal itself" could have decisive meaning, given such an immense transformation of an organism (Kammerer 1912a, 420).

The most challenging experimental problem is, with a characteristic of all living beings according to Helmuth Plessner, the "skin-like relation" (Plessner 1975, 123) of the amphibian olm with its environment. Exposed to light, the olm's pale skin turns black or freckled with black spots. The pigmentation of the olm's skin in the light prevents the light from entering the olm's body unhindered and from influencing growth. The olm lives in darkness when in light. Kammerer invents counter measures, including regular massages of the eye area and chemicals that destroy the pigment. Finally, he comes up with a trick that will turn his experiments into an historical media event. He substitutes the sunlight with the light of a photographic darkroom. Once one of the light olms develops more pigment, it is placed in the darkroom for a week and is exposed to red light. The intensity of the red light is increased "in that the bulb was directly hung in the olm's tank and burned exactly above water level" (Kammerer 1912a, 432).[15] The red light, however, is "ineffective in the creation

[14] A more detailed account forthcoming in: Berz, Hoffmann, Müggenburg (cf. footnote 4).

[15] This also would be a contribution to "Die Glühbirne als Laborstandard," cf. Berz, Hoege and Krajewskij 2001, 107-113.

of pigment," as other pigment experiments have shown (Kammerer 1912a, 432).

The first series of experiments included one week of darkroom and two weeks of sunlight for eighteen months, then full sunlight. Of course, there is the control experiment: "One olm was never taken into daylight, but lived in the red-lit darkroom from birth on." The rhythm of the light is in line with the laboratory rhythm: it is turned on in the morning and turned off in the evening. It consequently lives like the daylight animals in the "rhythm of day and night" (Kammerer 1912a, 434). The result? "I ended up having olms with *large eyes* that were black-brown but whose skin, even if richly pigmented, had not turned as dark as it would have in the case of constant light impact. It was obviously due to this that the light rays could go directly through to the eyes to produce the tremendous changes found there" (Kammerer 1912a, 432, emphases by Kammerer).

Strictly speaking, five great-eyed olms grow up. Not the least will Kammerer's skill in making photographic portraits lead to his international fame – and to his downfall. The glance, however, with which an animal looks back on this photograph, comes from an abyss different from the bars of a zoo. It is the abyss of knowledge itself.

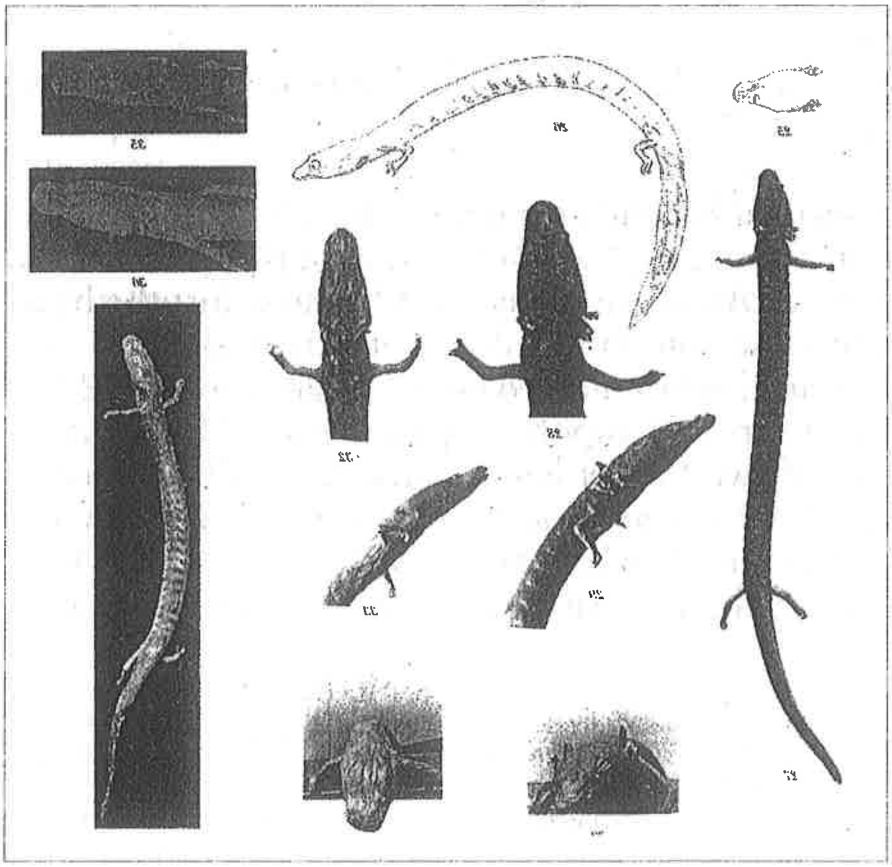


Fig. 5 - Portrait of a great-eyed olm (Kammerer 1912a, Plate XXIII).

When histologically prepared, the eyes look less frightening. This means, however, to behead the olm, to fixate it in formol-ice-vinegar, and to cut the eye open layer by layer with a razor blade: *Le Protée andalou*.[16] The evidence is there at the end of the exact histological interpretation of the cut: olms have a histologically fully-developed vertebrate eye. This can be shown by Kammerer cell layer by cell layer, from the lens to the retina.

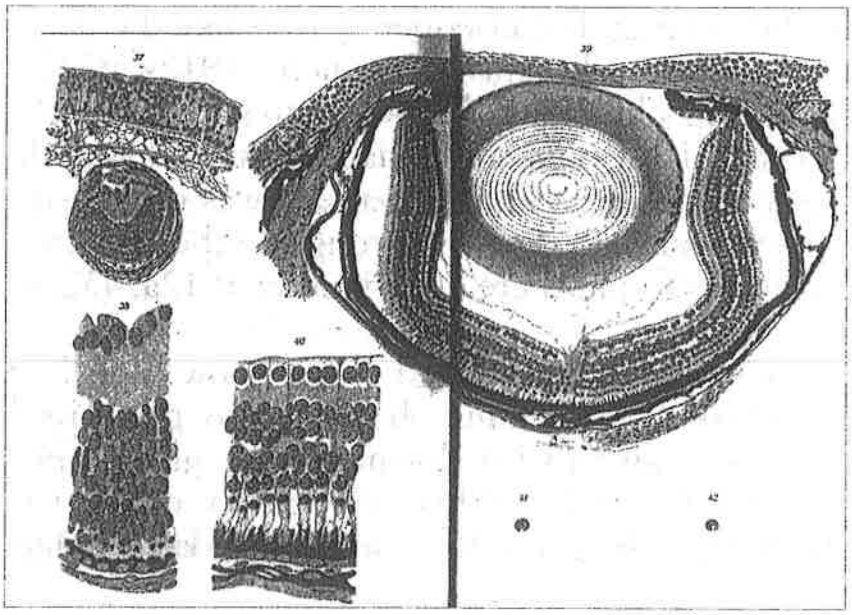


Fig. 6 - Histological cuts of a young dark olm and an old light olm (Kammerer 1912a, Plate XXIV).

The first scandal resulting from the animal looking back and from the scientific drawing of the new organ is the simple question, what exactly developed there? An organ of vision? Or, was it just the histology of an organ that could see but in fact does not see? In short, "can olms really see with their artificially enlarged eyes?" (Kammerer 1912a, 432).

When Kammerer's temporary assistant and lover, Alma Mahler-Werfel, tells her own former lover, Oskar Kokoschka, about the olms,[17] the painter answers very briefly the question as to what they see: "Well, Paul Kammerer, what else?" (Mahler-Werfel 1963, 45-47). The primordial scene of eye research that surprises Antoni van Leeuwenhoek

[16] "The taxidermist Carl Bergmann from the zoological institute cut the piece into layers of 0,010 mm in breadth, colored with delafield haematoxylin, orange and fuchsine" (Kammerer 1912a, 434).

[17] In order to forget the musician and his music, Alma Mahler-Werfel begins to work in a laboratory of the Viviarium in fall, 1911, following the death of Gustav Mahler and on invitation by Kammerer. She is assigned to work on the question put to her also on a pro-domo basis by Kammerer of whether the praying mantis forgets its painstakingly acquired habits (such as looking for food in the darkness rather than in the direction of the light) when shedding its skin (see also Mahler-Werfel 1963, 45-47).

in the 17th century and Michael Land in the 20th century is when they look in their microscopes and see themselves, one because he multiplies in a compound eye, the other because he has discovered a new mirror compound eye (Land 1999, 325; Land and Nilsson 2002, 106 sq.). This primal scene would imply the question, played back in a different dimension, if, what, and which kind of world Kammerer's olms see.

In order experimentally to explain the "psychological question" of the light olms' vision, Kammerer sets out on a second series of experiments derived from his practice of caregiving. There is only one tactical way in terms of experiments that leads to further investigation of the bred light olms' sense of vision: to compare the behavior of the blind dark olms with that of the light olms. The experimental problem lies in the relation of the olm to its environment. Olms are real monsters of sensitivity. They react to the faintest of vibrations, even to the earth's magnetic fields and chemistry. As Kammerer states, "Even the blind olm, with its stunted, undeveloped eyes, acts as if it could see" (Kammerer 1913, 433). Its entire skin is extremely "light sensitive," even its tail. The blind, feral olm also flees from glaring light and will immediately swim toward darkness. In addition, the olm moves straight and unerringly towards food, when it is "healthy, tame and hungry" (Kammerer 1913, 435). Yes, it is even capable of learning. Kammerer tries to turn the negative, that is, the light-fleeing, into positive, light-seeking phototaxis by using a flashlight with each feeding (Kammerer 1913, 434 sq.). It does not take long before the animals are soon swimming after the light, instead of fleeing from it. Among the forty olms participating in the experiment, a thirty-centimeter long female was the most responsive. Scientifically, it unfortunately does not carry any weight that several of the animals were not just content with swimming after the light but also "begged for food directly in the light by moving their bodies upright in the water, sticking their snouts out, snapping their jaws and snatching the food out of the hand. They even crawled into the hollow of the hand, showing not the slightest timidity, and searched for food between the fingers with their blunt, spatulated snout" (Kammerer 1913, 435). The adaptation to luminous stimuli is higher with kept olms, and the number of "tamed specimens bordering on impertinence" is even higher (Kammerer 1913, 435).

Thus, the experimental comparison between light olms and control olms is difficult. Even "putting a black rubber hood over a light olm's head" does not really do anything (Kammerer 1913, 435). The animals try restlessly to free themselves until they are finally able to remove the hood by slipping it off over a rock. Extirpation of the eyes is forbidden, however, as the light olms "are precious and rare" (Kammerer 1913, 436). There are only four extant specimen which must serve for breeding and as conservation.

The solution is ultimately a small, experimental arrangement. Kammerer remembers that axolotl, which are related to olms in diverse ways, also snap at food when placed in front of a glass pane. To isolate visual ability, Kammerer puts the olm in a small aquarium which has been placed in a larger aquarium. This shuts out all influences, such as smell and direct water movement created by even the faintest of air drafts.[18] What follows is the experiment with the "foetid earthworm (*Eisenia foetida*)" on a string: the light olms snap at the glass pane, according to Kammerer, in a "strict, spatial relationship to the moving object held up to them." In contrast, "not one worry-eyed olm, no matter how tame, was able to react to a moving object of prey that was not in the water with it" (Kammerer 1913, 437). Kammerer claims that a certain specimen snapped at it "fourteen times altogether," which translates, academically speaking, to "the positive reaction to the visual impression made by the movements of the alluring object." No matter how sparse this evidence may be experimentally, it clearly demonstrates one thing for Kammerer: light olms can see.

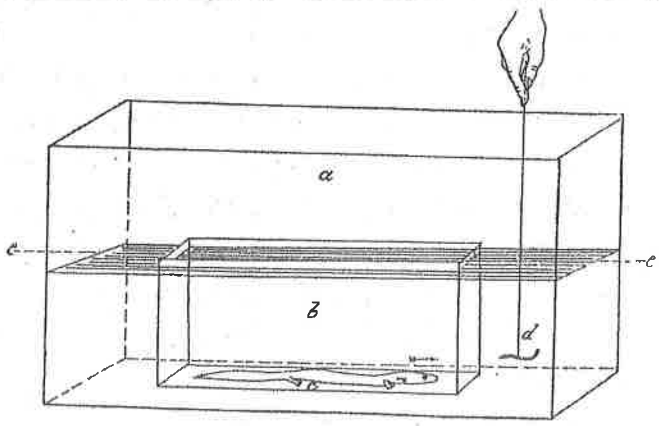


Fig. 1.

Fig. 7 - The two aquaria for testing the olm vision (Kammerer 1913, 439, Fig. 1).

Arguments

The argumentative scandals and challenges that lie in the simple fact that blind olms can grow eyes are, however, still not obvious. It has only recently become clear what was at stake with Kammerer's light olms between 1906 and 1920 – and what is, perhaps, scientifically still at stake.

The chapter on the "Regression of Eyes in the Proteus Species,"

[18] This set-up also shuts out the disturbing reflection of light in the transition from air to water; the small aquarium also does not contain any small objects which could serve as hiding places.

which appeared in 2001 in volume 14 ("Amphibians") of the French standard work, *Traité de Zoologie*, converges on the question of whether this regression has an adaptive character, which thus enables adaptation to darkness. The paleness of the skin is, for example, an adaptation to the darkness of caves. "Degeneration of the eye is different, although the effect of darkness is often emphasized. To expose the eye of young proteus to daylight or artificial light for over ten years! – it degenerates in spite of everything" (Durand 2001, 635).

The attempts at explanation have, up until now, all been pointless. Experiments in removing neoteny by administering hormones, for example, show that the skin continues to grow but not the eye. Thus, neoteny is eliminated as an explanation. The proteus' eye did not develop further when transplanted in other kinds of amphibians but the eye of other amphibians did continue to grow when transplanted in proteus. There is also the blind cave fish *Astyanax fasciatus*, which has a blind subspecies and a subspecies that can see and which have been cross-bred. What happened? The eyes disappear and re-emerge strictly according to Mendel's rules. The environment does not matter: the proteus' eyes develop regardless and degenerate. Ontogenetic adaptation to environment, the inheritance of acquired traits, reversibility of development, and the influence of neoteny: all this, according to the *Traité*, can no longer apply. "The determination of eye degeneration is genetically conditioned" (Durand 2001, 636). The current biological view of the world thus would have been saved. But what happened at the Vienna Prater from May 1906 until April 1911?

By 1920, the olms have fallen victim to scientific conservation and the First World War: During the war, the animals in the Vivarium are in danger of starvation, the difficulty in obtaining fresh water is immense, and Przibram and Kammerer sell their libraries in exchange for food. The situation in 1920 is also perhaps a personal one: no more amphibians, only popular education in Red Vienna and international fame as a coveted lecturer in England and the USA, where Kammerer is received with enthusiasm. *The Daily Express*, 1 May 1920, page one, after a reporter was able to smuggle himself into a meeting of the Natural History Society, where Kammerer gave a lecture, stated:

> *Brilliant scientific discovery!*
> *Eyeless animals grow eyes!*
> *Scientist claims to have discovered transference of good traits!*
> *Genius is hereditary!*
> *Transformation of mankind!*

Everything is cabled to America and arrives earlier than Kammerer, as reported in the *New York Times*, 5 May:

Scientist reports success where Darwin failed
Olms develop eyes
Proof of the inheritance of acquired traits
Kudos for Austrian scholar
Picture caption: *"Celebrated as a second Darwin."*[19]

Thus, in 1920 Kammerer formulates his big question in a long article on the olm experiments from 1906 entitled, "Dark Animals in the Light and Light Animals in the Dark," which is, can a bred-organ also be inherited? At the time he did not follow the tempting possibility of "raising a second generation of great-eyed olms in the dark and shady cistern" (Kammerer 1920, 29a). However, the question would have by no means been whether the new eyes could be completely inheritable. The question would simply have been whether "perhaps a second generation would have proved less 'reactionary' than the offspring of the dark olms in regard to eye regression" (Kammerer 1920, 29a).

The argumentative environment for the answer to this question is difficult. August Weismann and Kammerer's colleague, Megusar, argue that when a characteristic changes and allows itself to be changed, this provides enough evidence that it cannot be genetically transmitted. When, however, a characteristic is transmitted according to Mendel's genetics, it cannot become changeable. This is a dilemma which, according to Kammerer, amounts to the abolition of development as a whole; i.e., to the "belief of constancy" dating to the 17th and 18th centuries.

Kammerer does not doubt that the "rudimentary presence of the eye constitutes an inheritable trait" (Kammerer 1920, 31a). It all depends on how stable and unstable inheritable traits are under certain conditions. It is a matter of "transition from *stability to instability and vice versa*" (Kammerer 1920, 30b; italics in the original). In order for new species to develop, "their life streams must be deflected from the old riverbed and able to persevere in the fresh current of the new." One day, C.H. Waddington's evolutionary theory of "chreodes" and "epigenetic landscapes" will use the same terms and the same scenic images of evolution, which will inspire the French mathematician René Thom in his morphogenetic theory.[20] In *Allgemeine Biologie* of 1925, Kammerer then makes the scandalous demand that the "form of olm (*Proteus anguinus*) created by his experiments be classified as a separate species" (Kammerer 1925, 287).

[19] Quote from Koestler 1974, 105-107.

[20] Cf. Waddington 1970 [1968] and Thom 1977 [1972]: foreword and 112-117. Waddington pronounces Thom's work as a "book titled 'Structural Stability in Biology'" at the symposium organized by Koestler in 1968 (Waddington 1970 [1968], 350).

Kammerer argues from a practical point of view. The experiment's careful measures, such as how "to protect the delicate eye of the young olm from the dark if it should traverse the steep path to the functional eye" (Kammerer 1920: 31b), meaning the gentle transition from sunlight to the dark room and back – instead of just ten years of constant daylight or exposure to a light bulb as in the *Traité* – prove that it has to do with more than just an arbitrary exposure to light. A greater resistance must be overcome. The obvious counter-test of whether above-ground relatives lose their eyes when placed in darkness was negative. "Nothing to that effect can be observed!" (Kammerer 1920, 31a). Kammerer will also reinterpret this as a strong argument and root of a socialist-monistic utopianism: characteristics are more easily *acquired* than *lost*. Or, as the experiments with the new and obviously inheritable coloration of the fire salamander acquired by mimicry seem to prove: new characteristics are stronger than the old.

A second argumentative environment of the olm experiments and another set of contradictions, in addition to Weismann's, are the mutation theories of heredity as advocated by Lucien Cuénot and Jacques Loeb (Kammerer 1920, 32a). Cave animals look as they do only through random mutation. As such, "blind creatures, those with poor eyesight or those who are pale or bleached out, feel irresistibly drawn to dark, damp, cool places" (Kammerer 1920, 32b). This means that mutation due to "unknown, inner causes" (Kammerer 1920, 32a), according to Kammerer, and migration, are the reasons why blind animals live in dark caves, not because of direct adaptation to the environment or Darwinian selection.[21]

A third argumentative environment of the Kammerer experiments is in immediate institutional proximity to Eduard Uhlenhuth's 1911 experiments with amphibian eyes in the *Biologische Versuchsanstalt*. They originated from a broad field of experiments with amphibian eyes around the turn of the century that were common in developmental biology, especially since the works of Hans Spemann. [Spemann later became the colleague of a young professor in philosophy, named Martin Heidegger, who thought of the biologist as a "Wissensführer" (cf. Heidegger 1983, 279-280).] Developmental biology according to Spemann is a science of transplantation; that is, a science of operation, no less than physiology, but not a science of breeding.

Spemann begins to experiment with and operate on amphibian eyes in 1901. He observes how eyes grow in the abdominal region of a frog

[21] The so-called "migration theory" was mainly developed by a founding figure of geopolitical thinking in Germany: Moritz Wagner, Friedrich Ratzel's teacher and friend.

embryo or, after a general disruption of the diencephalic development, a Cyclops eye in the forehead. Spemann discovers the morphogenesis of the eye as an organ in amphibian eyes, in this case in the eye of the frog *Rana fusca*. The optic bulb everts from the diencephalon, then the bulb develops an inward vault, or invagination, and this vault "induces" the lens. Spemann's discovery – a hierarchy of organizers and inducers – controls the development of the eye and also controls degeneration. The question of whether organs develop "according to their location" within the entire organism or "according to their origin," i.e., genetically, is still posed today. Development according to location in a hierarchy of spatially localized inductors and organizers constitutes a part of what modern biology calls the "internal environment" of the organism (cf. e.g. Wuketits 2005, 66-70).

At the Vienna Viviarium, however, one does not experiment with frog embryos but with amphibian larva and with the transplantation of entire eyes, more precisely, with the eyes of *Salamandra maculosa*, the first protagonist of Kammerer's genetic theses (cf. e.g. Kammerer 1912b). In 1911, Kammerer's colleague Eduard Uhlenhuth transplants – *horrible dictu* – a salamander's eyes from its head to its neck. And lo and behold, the eyes continue to develop fully.

It seems to be evident that such an eye does not see when it looks at us. This is exactly why it poses the general question which forms the basis of the entire organ development in a particularly distinct way, a question which Heidegger and Lacan will also deal with one day: how are organ and function and function and organ development related to one another?[22] According to Uhlenhuth, the eye was particularly suited to the case. For, "in the construction of the eye, a particular function was sharply distinct and could easily be suspended by the experimenter" (Uhlenhuth 1911, 724). The fact that the eye integrates itself and grows in the new position following transplantation cannot be due to the function of the eye, by "functional stimuli" or by Roux's "functional adaptation" in which Lamarck's use of organs and its effect on the further development or degeneration of an animal reappears.[23] As Uhlenhuth writes:

> In my view, the application of the principle of functional adaptation to this case seems to be entirely incompatible with the facts [Uhlenhuth's own transplantation experiments with salamanders, PB]. If we wanted to accept it, we would have to assume that an eye also functions without being connected to the [brain] centers.

[22] Cf. Heidegger 1983, 311-333, para. 51-53 and Lacan 1964/1980, 97-103. For the current philosophical-biological discussion concerning the function, cf. Schlosser and Weingarten 2002.

[23] Cf. e.g. Kirschner 2003, especially 72-74 as an introduction. Also essential, Mocek 1998.

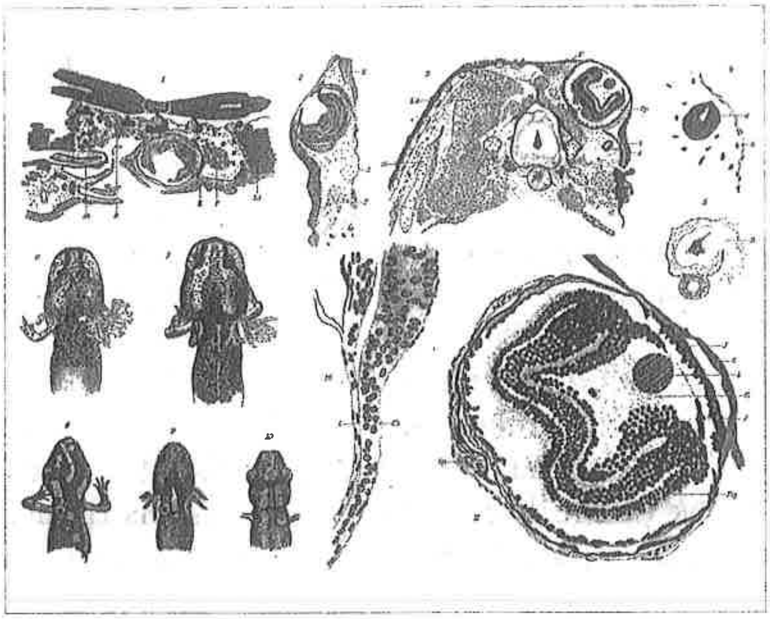


Fig. 8 - Uhlenhuth's salamander, especially nos. 8, 9, 10 (Uhlenhuth 1911, Plate XXXI).

> However, since its function consists of informing the organism about the light processes in its environment, it is clear that the transplanted eye is inoperative when not connected to these centers. Therefore, it would have to degenerate completely. Even if we wanted to admit that the eye's function was restricted to the transformation of environmental stimuli by the light-sensitive substances in chemical energy, it would not help, as optical cells do not exist for up to at least eight days following transplantation. In this case, the result would also be complete inoperativeness for a lengthy period of time. (Uhlenhuth 1911, 740)

Since the eye develops and the organ grows, becomes, and exists, and this completely without sight, the organ seems to have precedence over its function. Lacan's puzzling question as to the separation of the organ from sight as its function would need to be considered here, also from a scientific-historical viewpoint: "How long, one could ask for example, has the function of this organ [the eye, PB] existed and when is it simply just present in this line of creatures?" (Lacan 1964/1980, 97).

Environmental Knowledge

It is only at this point that the entire effort of Kammerer's experiments becomes apparent. In these experiments, the question as to function is also raised retroactively. In Kammerer's case, the development of the organ until "it is simply there" is not brought about by operations and transplantations to other areas of the organism or other areas of development within the inner environment. According to Kammerer, the development of the eye is the result of changes in the exterior environment of the creature. The eye experiments count on the flexibility and robustness of the olms, which make relocation from the Škocjan Caves to the underworld of Vienna possible when they manipulate the environmental variables in a calculated manner. But what is the exterior environment, and what are its effects? What is the origin of its scientific history?

Environment is dichotomous, according to Jean-Baptiste Lamarck. First there is the environment of use, exercise, and function of the organ. Second, there is the environment, to which Lamarck's second and lesser-known book of the *Philosophie zoologique* is dedicated: warmth, chemistry, electricity, magnetism, and gravity. Lamarck addresses this environment as "les milieux." Arnold Lang's 1876 German translation, commissioned by Ernst Haeckel, unceremoniously uses the word "the media." These media are not a hostile and therefore functional environment but rather media of direct stimulation, even excitation. "Fine, invisible fluida which are in constant movement, pervade all media – tous les milieux – inhabited by living bodies" (Lamarck 2002 [1809/1903], vol. II, 47; 1994 [1809], 351). According to Lamarck, the stimulation provided by these media can increase until spontaneous procreation takes place, as assumed by the 18th century. For Kammerer, the creatures live in a "constant state of general excitement" (Kammerer 1925, 59).

This second environment by Lamarck in Lavoisier's chemistry rebuffs this combination of science with its mysterious, omnipresent basic substance of *calorique*. According to Lavoisier, "all of nature's bodies are dipped, surrounded, and saturated in *calorique*, it fills all the spaces left by their molecules" (Lavoisier 1864, 141). However, Lavoisier's chemistry combination board first contains light and the first question put by his chemistry is, what is light combined with? It appears to combine with air, and the green of plants and the color of blossoms also seem to join with light. They become pale in the dark and are transformed "into a condition of yearning and suffering." They need the "immediate influence of light" in order to regain their natural strength. One notices the same thing with animals. Men, women, and children become pale when working in a sitting position or living in cramped apartments on narrow city streets (Lavoisier will come up with a plan to improve street lights in large cities). Light, although difficult to define in chemical terms, appears to be a general strength. "Organization, feeling, spontaneous movement, life, only exist on the earth's surface and in places exposed to light. One could say that Prometheus' fire was an expression of philosophical truth that has not escaped the ancients. Without light, nature would be without life; it would be dead, inanimate. A benevolent God made light and spread organization, feeling and thinking over the face of the earth" (Lavoisier 1864, 142, Translation PB).

In 1809, Lamarck will develop this further into warmth, organization, feeling, and cogitation; in the "duplicated impressions which the internal and external objects exercise its organ by means of the senses," until finally the "origin of all animalistic ability," is found in the light (Lamarck 2002 [1809/1903, vol. II, 93). The distant, historical origin of Kammerer's olms is found here, one Darwinian-century earlier than the experiments in the Viennese Prater. In 1911, Hans Przibram, Kammerer's employer, drafts in *Roux's Archive* a program of future experimental projects for the Vienna Vivarium with the title "The Environment of Germ Plasmas." All physical relations which contain "gonads" should be examined in comparison with Weismann's germ-soma dualism. How do physical relations change in the face of environmental change? What is the relationship between "gonads and the rest of the body?" Przibram only needs to think further along the lines of the Lamarckian definitions of physical media: they are chemical, damp, impermeable, mechanical, heavy, electrical, radiant, and full of thermodynamic energy.[24]

Kammerer's report on his olm experiments is entered in *Roux's Archive* at the same time as Przibram's research program. In it, the development of an eye is not induced by the exercising and training of the visual function and not by the transplantation of cells or organs but rather without diversion and, according exactly to Przibram's program, by a physical medium, light stemming from various frequency areas and sources. "Only rays that do not accumulate pigment were able to bathe the eye in light: such rays bestowed the dark room with a red, glowing light that did not blacken the photographic plates, as is well known" (Kammerer 1920, 28a). The incident of Kammerer's light olms consists in directly combining the old, Lamarckian concept of a biological-physical medium with the technical medium of the 20th-century photography.

Such combinations are also used in other areas of the Biological Research Institute, and some are taken literally, in rather gruesome fashion. Kammerer's colleague Slavko Seçerov examines the light permeability of pigmented amphibian skin (also an important question for the olm experiments). Seçerov's work is deceptively titled "The Pleasure of Light in Salamander Bodies" (*Der Lichtgenuß im Salamanderkörper;* Seçerov 1911). The experiment consists of transplanting pieces of light-sensitive

[24] Cf. Przibram 1911. Przibram's canon follows the suggestion of the American biologist Charles B. Davenport.

photographic paper under the skin of spotted fire salamanders and observing when and how the salamander's skin pattern is transferred onto the paper. Light-sensitive skin and film, photograph, and pigment have become a single disposition.

Kammerer's commitment goes further then that of his operating colleague. He does not begin with photographic material as experimental item but rather with the materiality of development. Playing around with developing baths underneath red light becomes a direct environmental condition for biological development: the breeding of olms. "To bathe the eye in light," as Kammerer writes, and from there to "traverse the steep path to the functional eye" (Seçerov 1911, 31b), *to the sun, to freedom, rising upward to the light.* A science is born out of Kammerer's experiments, a possible and vanished biology of the 20th century that was intended as a radical and utopian science of the environment stemming from Lavoisier and Lamarck. From here the concept of biological development as such could one day be rethought.[25]

Vision as a bath may also be in the position to provide human vision with a new perspective: to think that was reserved for a great anti-Darwinist who is part of the rich Russian history of controversies with Darwinism. Ossip Emiljewitsch Mandel'stam's much longed for trip to the light of the Armenian mountains – an account of which appears in 1933 as a book with the same title – liberates the eye from its visual function in a chapter on vision and the contemplation of the French Impressionists. This is done in order to return the eye to its material environment and to create a physiological or biological environment of vision.

> Quietly, without sharpness – like the Tatar children in Alusha bathing their horses – you bathe the eye in the material of a new environment. And are reminded that the eye is a noble but willful animal . . . . [you stand] before a picture that has not yet conformed to the body temperature of sight, and for which the crystal lens has not yet found a way to adjust....When this equilibrium has been achieved . . . , [then] the second stage of restoring the picture begins, its ablution, peeling away the fragile skin, the barbaric most outer and tardy layer which joins the picture – as everything – with a sun-drenched and condensed reality. . . . The eye pulls the picture to it by the finest acid responses....because painting is to a large extent more a phenomenon of inner secretion then of apperception, i.e. an external awareness. (Mandel'stam 1994, 36 sq)

[25] Kammerer's environmental knowledge found itself in an impermeable, discursive environment during the First World War. Albert Jesionek's "Lichtbiologie" of 1910, a contemporary during Kammerer's experimental period, is partially devoted to the effects of light on plants, bacteria and microorganisms. The other half deals with – going out from the "effect of light on advanced animals" – the "experimental basis of modern light treatment"; the effects on human skin, blood, metabolism and the nervous system. And lands at, "according to Goethe, the 'sensuous-ethical effect of colors'". "Were the eye not like the sun, the sun could never behold it." I will refrain from mentioning the light cult at Monte Verita for now (cf. Jesionek 1910).

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