First publ. in: Observing nature - representing experience : the osmotic dynamics of romanticism 1800 - 1850 / ed. by Erna Fiorentini. - Berlin : Reimer, 2007. - S. 187-203. - ISBN 978-3-496-02803-1

Bernhard Kleeberg

Ideal (Geometrical) Types and Epistemologies of Morphology

When in 1867 botanists Carl Nägeli and Simon Schwendener published their work on the microscope and its usage, they warned that using this optical device would never lead to a thorough comprehension of the observed – the microscope could only present a corrupted picture of the object. Since the knowledge gained could never transcend the "received impression" of the beholder, there was "no truth further advanced than a relative natural truth."[1] Nägeli and Schwendener held that the same standards of perception were valid for all kinds of observation of nature, and the glance through the lens of the microscope in the end only complicated the question of subjective perception. The visual device introduced additional problems of aberration from true perception, since besides the general virtues of the naturalist, correct judgment and full scientific comprehension of the object, technical connoisseurship was needed. Drawing the observed objects provided further difficulties, even if the aim was to merely reproduce the received impression, or if tools could be used to help the less skillful draftsmen amongst the scientists: the use of these demanded conscientiousness, dexterity, and careful training.

Yet though Nägeli and Schwendener reminded their readers not simply to rely on technical devices since they only increased the epistemological problems of perceiving with the naked eye, they advocated principles of observation and representation that had broken with early nineteenth century visual regimes. Representations of nature were not necessarily to be judged by comparing them to the observed objects – other criteria were

1 Carl Nägeli and Simon Schwendener, *Das Mikroskop. Theorie und Anwendung desselben* (Leipzig: Wilhelm Engelmann, 1867), 284: "Wer sich einlässlicher mit mikroskopischen Untersuchungen beschäftigt, soll im Stande sein, das Wahrgenommene in Abbildungen wiederzugeben, welche wenigstens in allen wesentlichen Punkten mit dem erhaltenen Eindruck übereinstimmen. Wir sagen: mit dem erhaltenen Eindruck, nicht mit dem Object selbst; denn eine weiter gehende Naturwahrheit, als eben diese relative, ist nicht denkbar. [...] Absolute Naturwahrheit bleibt übrigens für den Mikroskopiker ein Ideal, nach dem er zwar streben soll, das er aber immer nur annähernd erreicht. Seine Zeichnungen sind im günstigsten Falle doch stets nur mit Rücksicht auf diejenigen Punkte naturgetreu, zu deren Versinnlichung sie angefertigt wurden."
All translations are mine, except where indicated otherwise. I am grateful to Simon Cooke for proofreading.

accepted as well: functionality in respect to the aim of the scientist, uniformity in the standards of representation, or approximation to the perceived object.[2] Functional standards were related to the usage of the respective illustration within educational and research contexts, not to degrees of exactitude in representing a true or objective nature. For instance, meeting the explanatory aims of a scientist who wanted to point to a specific part of an object sometimes required including shadows and lights, while in other cases drawing merely a contour might be sufficient. Similarly, the epistemological value of "rational schematic" drawings depended on their functionality: their correct interpretation required uniform standards of representation, not necessarily likeness to nature in all its details. In order to show the right way through the labyrinth of nature, schematic drawings subscribed to one common principle of representation, regardless of what principle that might be – as practiced in cartography. In doing so, they could not at the same time be "photographically true to nature," thus could not follow the ideal of objectivity that "exact drawings" subscribed to.[3]

Detailed representations in the sense of a "photographical truth" followed the rule of approximation to the real object as perceived under the microscope. Here, every detail was regarded as relevant and had to be depicted. In order to achieve this, even connoisseurs needed mechanical instruments for exact drawing. Nägeli and Schwendener explain in minute detail how to use apparatuses that redirect reflections – prisms, the Soemmering mirror, or the *camera lucida*[4] –, and which technical skills were needed for the preparation of the object and to handle the microscope.[5] Otherwise, perceived features of the object might be mistaken for real qualities that in the end could turn out to be nothing more than mere deformations induced by the medium.

A famous example of how visual effects of the technical instrument could lead to misinterpretation was discussed by Nägeli and Schwendener's colleague, physiologist Rudolf Virchow in his *Cellularpathologie*: when French zoologist Henri Milne-Edwards – an expert in microscopy – more than forty years earlier observed little "globules" in his microscopic preparations from plants, animals, and humans, he considered them as forming the elementary structure of organic life.[6] Virchow pointed out that Milne-Edward's

2 Cf. ibid., 284–291.

3 Ibid., 289–291. On the epistemological goal of being "photographically true to nature" and "mechanical objectivity" cf. Lorraine Daston and Peter Galison, "The Image of Objectivity," *Representations* 40 (1992): 81–128.

4 The authors do not single out the "best" instrument – this, they reckon, is a question depending on habits and training of the user, as there are disadvantages to all of the different devices, see Nägeli/Schwendener 1867 (as in note 1), 284–288.

5 Cf. ibid., 188–190, 194f., 288. The authors hint to the difference between mediated microscopic and observation with the naked eye: microscopic images displayed inner reflections and an intensification of light depending on the respective media used for conservation (glycerin, oil, etc.).

6 Henri Milne-Edwards, "*Mémoire sur la structure élémentaire des principaux tissus organiques des animaux*", *Archives générales de medecine, série 1, Nr. 3 (1823)*: 165-184; idem, "*Recherches microscopiques sur la structure intime des tissus organiques des animaux*" *Annales de Sciences Naturelles, t.9 (1826)*.

observation had in fact been nothing but an optical illusion, induced by the medium: using mediocre instruments at full sunlight caused a dispersion of light that led the observer to the impression "that he saw nothing but globules." But since *Naturphilosophie* had cherished globules as the elementary constituents of animal bodies, corresponding to the first origin of all formed matter, Milne-Edward's slip was not astonishing, Virchow remarked: "old views, in part from the last century" had prevailed in many areas of physiology, necessitating scholars to judge on basis of their own "perception of objects" ["Anschauung der Objekte"] – which sometimes could be misleading.[7]

This essay takes up Virchow's assumption that the observation of certain morphological entities depended not only on technical devices and their correct handling, but on what was accepted as true nature.[8] The mid-nineteenth century claim that mechanical instruments were necessary to represent objects in every detail, approximating nature 'as it really is,' the methodological option to follow functional rules and use 'artificial' standards of representation that could not be found in nature in order to single out relevant details of the observed – these maxims of observation and representation seem to differ considerably from earlier approaches. Early nineteenth-century naturalists observed in a divergent manner: they did not look for specific objects and their detailed morphological structure, but sought to infer ideal- or archetypes from the observed world of phenomena. These were regarded as true representations of nature, and often reckoned to be geometrically ideal stereometrical bodies. In idealist and romantic morphology, these ideal forms served as mediators between scientific knowledge and the aesthetic experience of nature: denoting the inner beauty of nature, its unity and progression, they provided support for the scientific significance of an aesthetic experience of nature, and interconnected organic individuality to the whole of nature. Epistemological uncertainties evoked by physiological concepts on the subjectivity of perception were met by stressing the similarity of the fundamental formative principles of man and nature, or the mutual dependence of scientific and aesthetic experience.

7 Rudolf Virchow, *Die Cellularpathologie in ihrer Begründung auf physiologische und pathologische Gewebelehre* [1858] (4th ed. Berlin: August Hirschwald, 1871), 22f.; I am grateful to Eva Johach for giving me a hint to this passage.

8 Laura Otis, *Membranes. Metaphors of Invasion in Nineteenth-Century Literature, Science, and Politics* (Baltimore et. al.: Johns Hopkins Univ. Pr., 1999), 7, has pointed out that while microscopists on a practical level "began seeing cells because of improved achromatic lenses, they also saw cells because, as their own descriptions indicate, the idea of a bounded individual as the unit of life became culturally acceptable and appealing."

Ideal prototypes, flawed phenotypes

Following the platonic way from the diversity of nature to its unity and simplicity that Johann Wolfgang von Goethe had suggested in an aphorism,[9] concepts of ideal forms and their flawed appearances can be found in many morphological studies of the early nineteenth century. In his studies on the morphology of minerals, romantic natural philosopher and embryologist Lorenz Oken based his classifications on ideal geometrical constructions from platonic "basic shapes" that could be seen in crystals. Other means of classification, such as descriptions of their chemical element, color and dispersion, were of only secondary importance. Though a comparison between geometrical forms and crystals with their simple, regular and symmetric shapes (i.e. cube, octahedron, dodecahedron) might suggest itself, Oken did not only refer to the outward appearance of crystals as "blunted" or "tapered:"[10] All observed natural phenomena, whether crystals, plants or animals, were "flawed," "anomalous," or even "monstrosities," whilst the "normal," that is, the *perfect* forms, represented their true nature:

> *So vollkommen regelmäßig ausgebildet findet man aber die Crystalle selten in der Natur. Wir haben der Unvollkommenheiten derselben indessen bisher absichtlich nicht erwähnt [...], da wir hier, wie bey der Darstellung der Hauptverhältnisse der Thiere und Pflanzen und der Beschreibung ihrer Geschlechter und Gattungen, als deren Repräsentanten die normalen Gebilde und nicht die Mißgeburten betrachten.*[11]

Similarly, Swiss botanist Augustine Pyrame de Candolle argued that regularities were to be found in inorganic as well as organic bodies, though in the latter there was no true symmetry in the mathematical sense, but only a "pathetic regularity" ["rührende Regelmäßigkeit"].[12] Goethe's theory of metamorphosis opened up a way to conceive these deviations from ideal symmetry as something regular, by adding the dimension of time. Had de Candolle not based his organography on the notion of symmetry, thus suggesting that most of the botanical world broke with the basic principles of nature, Goethe

9 Johann Wolfgang von Goethe, *Wilhelm Meisters Wanderjahre. Drittes Buch: Aus Makariens Archiv*, in Werke (*Hamburger Ausgabe*), ed. Erich Trunz (München: C. H. Beck, 1998), vol. 8, 467: "Um sich aus der grenzenlosen Vielfachheit, Zerstückelung und Verwickelung der modernen Naturlehre wieder ins Einfache zu retten, muß man sich immer die Frage vorlegen: Wie würde sich Plato gegen die Natur, wie sie uns jetzt in ihrer größeren Mannigfaltigkeit, bei aller gründlichen Einheit, erscheinen mag, benommen haben?" On Goethe's view on nature in Wilhelm Meister and on Makariens Archiv see Safia Azzouni, *Kunst als praktische Wissenschaft. Goethes 'Wilhelm Meisters Wanderjahre' und die Hefte 'Zur Morphologie'* (Köln/Weimar: Böhlau, 2005), 194–207.

10 Cf. Lorenz Oken, *Allgemeine Naturgeschichte für alle Stände. Erster Band: Mineralogie und Geognosie* (Stuttgart: Hoffmann, 1839), 33.

11 Ibid., 126, my italics.

12 Cf. Augustine Pyrame de Candolle, *Organographie végétale ou description raisonné des organes des plantes. Pour servir de suite et développement a la Théorie élémentaire de la Botanique, et d'introduction a la Physiologie végétale et a la description des familles* (Paris: Deterville, 1827); Goethe commented on this in "Von dem Gesetzlichen der Pflanzenbildung" (*Naturwissenschaftliche Schriften 1827–1832*), in *Sämtliche Werke nach Epochen seines Schaffens*, vol. 18.2, 398f.

would generally have agreed with him: indeed, Goethe conceded that plants did follow nature's intentions – but due to the principle of metamorphosis that governed the realms of the regular as well as the irregular.[13] Asymmetries only provided further insights into regular development from the universal to the particular, the differentiation of the primordial unity of the "ideal" or "archetype." Deviations from regularity in shape could be integrated into a concept of universal regularity, since the emergence of these appearances still followed regular *causes*.[14] Phenomenal divergence from the prototype that often led to ill-informed classification had to be judged against two different kinds of underlying regularity: (1) *regularity of form*, concerning the archetype itself and the boundaries it imposed onto the development of an empirical individual, and (2) *regularities of morphogenesis*, the laws of metamorphosis.

For instance, the "Urpflanze" as the common pattern enfolding into individual forms[15] could be inferred from a multitude of samples, and the "hidden law" from a continuous sequence of events.[16] Alexander Rueger has argued that Goethe's ideal of science was a "narrative structure," embedding a subject into a story, describing and explaining at once and thus realizing the "empiricist ideal of a theory that is not really separate from the descriptions of the phenomena." Applauding Baconian epistemology, Goethe had thought that "the unprejudiced collecting of observations and facts" would reveal the underlying principles, the "pure" or archetypal phenomenon.[17] For Goethe nature revealed itself directly to the observer only if he did not pre-select his objects. His ap-

13 Goethe, *Pflanzenbildung* (as in note 12), 478. On the emergence of different parts from the ideal archetype cf. *Naturwissenschaftliche Schriften 1791–1797*, in *Sämtliche Werke* (as in note 12), vol. 4.2, 193. Timothy Lenoir, *The Strategy of Life: Teleology and Mechanics in Nineteenth-Century German Biology*, Dordrecht: Reidel 1982, 59f., refers to the concern for symmetry as a principal characteristic not only of *Naturphilosophie*, but of its critics as well (e.g. Johann Friedrich Meckel, Carl Friedrich Kielmeyer).

14 Cf. Goethe, *Pflanzenbildung* (as in note 12), 398f., my italics: "Wir können uns daher überzeugen, daß die scheinbaren Unregelmäßigkeiten der Pflanzen sich von Phänomenen ableiten, die beständig innerhalb gewisser Grenzen wirksam sind, fähig hervorzutreten, entweder gesondert oder vereint, wie das *Mißgebären* oder die *Entartung* gewisser Organe, ihr Verschmelzen unter sich oder mit andern, und ihre Vervielfältigung nach Regeln und Gesetzen."

15 There had to be an "Urpflanze" – how else would you be able to regard something as a plant, if they had not been formed after one common pattern, Goethe wrote in a letter in September 1787, after visiting the botanical garden in Padua; cf. Adolf Meyer-Abich, *Geistesgeschichtliche Grundlagen der Biologie* (Stuttgart: G. Fischer, 1963), 87–90. Meyer-Abich himself argues in the tradition of idealistic morphology.

16 On the "hidden law" cf. Johann Wolfgang von Goethe, "Die Metamorphose der Pflanzen" (1798), in *Goethes Werke: Hamburger Ausgabe in 14 Bänden*, ed. Erich Trunz (München: Beck, 1962), vol. 13, 64–101, 83. On sequences of events cf. idem, "Empirical Observation and Science" (1798), in *Collected Works*, ed. Victor Lange et. al. (New York: Suhrkamp, 1983–88) vol. II, 25.

17 Alexander Rueger, "The Cultural use of Natural Knowledge: Goethe's Theory of Color in Weimar Cassicism," *Eighteenth-Century Studies* 26/2 (1992/93): 211–232, 217ff.; cf. Goethe, *Empirical Observation* (as in note 16), n.19. ed. Karl Richter (München: Hanser, 1986),

proach thus followed what Lorraine Daston has described as the common practice of late eighteenth and early nineteenth century botanists: they based their description of a species "on as wide a range of specimens as possible," and distinguished the "essential from the accidental, the normal from the pathological, the typical from the anomalous, the variable from the constant."[18] Particularly when illustrating specimens it was necessary to detect the hidden law inherent in all the individuals of one type in order to construct the "true," common form. In this respect there was little difference between artists and naturalists: both selected "the most beautiful, that is, the most general form of nature."[19]

The dynamic concept of the enfolding archetype combined the platonizing notion of ideal shapes with the Aristotelian idea of stages of development, offering a basic but steadily transforming pattern. This fitted with the widespread concept of a vital force of development – the "Gestaltungskraft" (Karl Ernst von Baer) or "Bildungstrieb" (Johann Friedrich Blumenbach). Oken combined his notion of ideal forms with a developmental theory of nature, which he conceived to be riddled with inherent vital forces permanently creating organisms. The origin of all forms of life he saw stemming from marine slime, at first producing simple, cell-like organisms – the "infusoria," which then transformed into colonies and aggregates and, giving up their individual lives, into higher organisms.[20] The basic organic matter was no "bulky mash" but mucous vesicles – small globules, gradually getting hollow. As a result of mutual compression within the united cell structure these "cells" according to mathematical laws further developed into a "rhombic dodecahedron as the ideal form."[21] Here Oken argued with his colleague, physician Dietrich Georg Kieser, who regarded the cell as a "completely organized and

18 Cf. Lorraine Daston, "Type Specimens and Scientific memory", *Critical Inquiry* (Autumn 2004): 153–182, 166.

19 Cf. ibid., 168: the illustration showed an exemplar that never occurred in nature but was thought to represent the essence of a species, an idealized, abstract exemplar called the "holotype:" In the course of the 19th century the term "type" changed from signifying an ideal "pattern of form" or archetype to denoting natural particulars. Type specimens were accidentally, not essentially representative samples of the species, "emphatically not prototypes or archetypes or anything else smacking of the Platonic." (ibid., 164) Instead of collecting numerous specimens and then constructing a holotype, botanists and illustrators around 1900 described and depicted randomly chosen individuals and used a single, concrete specimen as the referring point for naming the species. Within this modern principle of representation, particulars were compared with particulars, not with universals – "the type of the species was typically no longer typical." (ibid., 176)

20 Cf. Lorenz Oken, *Die Zeugung* (Bamberg/Würzburg: J. A. Goebhardt, 1805). Higher organisms are that of new organs or organ-systems, complexity is a token of the organism's level of development, the cell forming the elementary organ with specific geometrical form and physiological functions; cf. Ilse Jahn, "'Biologie' als allgemeine Lebenslehre," in: *Geschichte der Biologie*, ed. idem (Jena et.al.: Gustav Fischer, 1989), 290f.

21 Lorenz Oken, *Allgemeine Naturgeschichte für alle Stände, Zweyter Band* (Stuttgart: Hoffmann, 1839), 13f.: "Man hat früher gemeynt, die Grundmasse des Organischen sey ein unförmiger Brey, den man Breystoff nannte. Ich habe aber schon vor vielen Jahren [cf. Oken 1805 (as in note 20)] zu zeigen gesucht, daß sie aus lauter Schleimbläschen bestehe, und mithin schon bey ihrem ersten Auftreten gestaltet sey. [...] Man kann den Anfang der organischen Grund-

individualized body," an "Urform," further developing through vertical (in plants) or horizontal (in animals) metamorphosis.[22] To focus the attention on a single organ and than follow its transformations through various forms in different organisms was a common practice in romantic natural philosophy, as Timothy Lenoir has pointed out. Like Goethe, Geoffroy Saint-Hilaire, Karl Friedrich Burdach, Carl Gustav Carus and other romantic naturalists interpreted developmental sequences of related organs on basis of the *geometrical* transformations of their basic forms.[23] In a passage reminiscent of natural theology, naturalist Hermann Burmeister for instance spoke of the "mathematical lawfulness" of shapes of leaves, in which "nature lays out an inexhaustible richness of forms and reveals the abundance of her imagination in this manifoldness, only limited by certain archetypes, in a marvelous way."[24]

Oken's description of the cell as a "globule" indicates that he conceived the smallest of all units – the primordial form of life – as having a distinct geometrical shape: it formed a *sphere*. Like most of his contemporaries he took the sphere to be the archetypical organic form, from which the variety of shapes emerged through processes of polarization and differentiation. The origins of life, physiologist Ignaz Döllinger put it in 1805, could be seen as a transition from an amorphic mass to a distinct form, its first product always being spherical like globules or bubbles.[25] Like Oken, Döllinger regarded "Bil-

masse als weiche Puncte oder Kügelchen betrachten, welche allmählich hohl werden, indem sich durch Oxydation der Umfang verdichtet und das Wasser sich in der Mitte sammelt. "

22 Oken and Kieser had jointly published *Beiträge zur vergleichenden Zoologie, Anatomie und Physiologie* (2 vols., Bamberg: Göbhardt, 1806/7). Kieser's ideas on the "Urform" and vertical and horizontal metamorphosis can be found in "Ueber die urspruengliche und eigentuehmliche Form der Pflanzenzelle," *Nova Acta physico-medica Acad. Caes.-Leop. Nat. Cur* 9 (1818): 57–86. Besides Oken, Matthias Jacob Schleiden and de Candolle subscribed to Kieser's view. On Kieser, who was collaborating with Goethe and Schelling as well and wrote on typical themes of *Naturphilosophie* like micro-macrocosmic analogy and universal harmony, cf. Walter Brednow, "Dietrich Georg Kieser, Sein Leben und Werk," *Sudhoffs Archiv, Zeitschrift für Wissenschaftsgeschichte* Heft 12 (1970); Jahn 1989 (as in note 20), 292. For the history of Kieser's ideas on the dodecahedron cf. Lazarus Walter Macior, "The Tetrakaidecahedron and Related Cell Forms in Undifferentiated Plant Tissues," *Bulletin of the Torrey Botanical Club*, vol. 87/2 (1960): 99–138, 100. Interestingly, Macior during the 1950s still uses the *camera lucida* to draw cells (ibid., 114f.).

23 Cf. Lenoir 1982 (as in note 13), 75–77. In contrast, morphologist von Baer had never treated shape and its geometrical transformations as fundamental, but in relation to functional laws. Furthermore, he had dismissed external symmetry of bodies as of little use in discussing internal structures.

24 Hermann Burmeister, *Geschichte der Schöpfung. Eine Darstellung des Entwicklungsganges der Erde und ihrer Bewohner. Für die Gebildeten aller Stände* (5th ed. Leipzig: Wigand, 1854), 339f.

25 Ignaz Döllinger, *Grundriß der Naturlehre des menschlichen Organismus, zum Gebrauche bey seinen Vorlesungen entworfen* (Bamberg et. al.: Goebhardt, 1805), 23f., 33ff. Since globules had to be classified as standing in between the solid and the liquid, the transition occurred due to solidification. Because of their fragile character, bubbles in experimental physics since the mid nineteenth century (Maxwell, Faraday, etc.) served as models for air molecules and ether. Robert Chambers in 1845 spoke of the "dew-drop" as "picture of the world" in physics, depicting formation and arrangement of the solar system: cf. Simon Schaffer, "A Science Whose

dung" as the primordial activity of the universal organism of nature. Both drew heavily on Friedrich Wilhelm von Schelling's principle of polarity as the driving force of the morphogenetic process that led different parts to form an organic whole.[26] Yet in contrast to Oken, Döllinger was concerned to develop observational techniques capable of eliminating speculation. While "pure philosophy is immediate knowledge of the Absolute," Döllinger wrote in 1805, "knowledge of finite things," "could only be provided by experience." The construction of physiology had to follow the path from observation to philosophical reflection.[27]

Yet there was more to these ideal shapes than representing observed cellular or microorganismic material. Romantic *Naturphilosophie* conceived the sphere as the ideal of unity and simplicity, underlying the micro- as well as the macrocosm. Though romantic naturalists like Carl Gustav Carus underlined the importance of accuracy in observation and description, they did so not for sake of particular details, but to supply an exhaustive basis from which universal principles could be inferred. According to Carus, the smallest possible morphological unit had to be deduced from a most simple and primordial universal form that lay hidden beyond the realm of the visible, a geometrical "Form an sich."[28] Following the "great law of genesis," the progression from the universal to the particular, there was only one body that met these criteria: "The spherical shape or the globe." "Die Kugel ist somit das wahre Zero der Formenwelt."[29] From this "Urform" all

Business is Bursting: Soap Bubbles as Commodities in Classical Physics," in *Things That Talk: Object lessons from Art and Science*, ed. Lorraine Daston (New York: Zone Books, 2004), 147–192, 164.

26 For the principle of polarity see Friedrich Wilhelm von Schelling, "Von der Weltseele" (1798), in *Schellings Werke, 2. Hauptband: Schriften zur Naturphilosophie 1799–1801*, ed. Manfred Schröter (München: Beck, 1927), vol. I, 635–637. Döllinger adopted the principle in *Über die Metamorphose der Erd und Steinarten aus der Kieselreihe* (Erlangen: Iohann Iakob Palm, 1803). Cf. Lenoir 1982 (as in note 13), 66f.: For Döllinger, "nature as originally undifferentiated unity containing within it various dimensions of potency related to one another by polar oppositions. These polarities provided the mechanism for the material genesis of form [...]." Though Döllinger by and by turned away from his earlier speculative approach, he followed the goal of constructing a dynamical morphology, and regarded life as "in essence *activity*, motion, reciprocal interaction giving rise to form."

27 Döllinger 1805 (as in note 25), cit. after Lenoir 1982 (as in note 13), 70.

28 Carl Gustav Carus, *Natur und Idee oder das Werdende und sein Gesetz. Eine philosophische Abhandlung für die specielle Naturwissenschaft* (1861) (repr. Hildesheim et. al.: Olms, 1990), 39ff.; For insights into Carus I am indebted to Ingrid Wurst.

29 Carus 1861 (as in note 28), 41. Its primordial motion being rotation, as "das Hervortreten alles Besonderen immer nur eben durch innere Differenzierung allgemeinen Aethers möglich war, und da auch fernerhin und fortwährend alles organische Werden und Wachsen stets und allein durch innere Differenzierung eines vorher mehr oder weniger Indifferenten zu denken ist [...], so daß, streng genommen, es eigentlich überhaupt nur innere Bewegung giebt, insofern das Weltganze stets als ein an sich unendlicher Organismus gedacht werden muß" (ibid., 56). Inner and outer motion, whether of the earth ("Weltkörper"), blood, the turning of the wheels, or machines were all expressions of eternal divine thoughts, following eternal laws (ibid., 59).

other forms evolve in a spiraling movement of the great chain of being,[30] either by contraction or by expansion: Contraction leads to the platonic shapes – to the cube, then to the octahedron, the dodecahedron and so forth. Expansion leads to the form of the egg, followed by the cone and the cylinder,[31] furthermore developing into irregular bodies. Hence, the higher developed an organism, the less obvious its geometrical form. The early stage of development of the human body, for instance, has spherical shape – while enfolding, it constantly and gradually gives up strict mathematical form. While the morphogenetic development of higher organisms starts from the simple and universal form of the sphere, primitive organisms emerge from irrational forms, as could be seen in the shape of the infusoria.[32] Yet, Carus like Schelling and Oken emphasized that regular, symmetrical, that is: *rational* forms were to be found everywhere in nature, even when a body seemed to be of arbitrary shape. Regularity might be revealed by looking at details – demanding *accurate* representation –, but this observation had to be guided by knowledge of the morphogenetic laws. Having microscopically examined and drawn a "volvox globator," a globular proto-organism, he stated that this strange kind of being, looked at in a drop of water, was like a "Weltkörper," calmly rolling about.[33] On the other hand, a line drawn on paper, when looked at through the microscope, seemed to be merely a "disordered amassing of spots of ink," though its real essence lay in being a line: thus, the "phantasmagorias of the senses" had to be transcended, the observer in a platonic manner had to trace the significant behind the insignificant, "the [prefactual] behind the factual."[34]

30 The natural chain of being transforms in the eternal metamorphosis, a spiraling movement (ibid., 60f.). Carus refers to Schelling and Goethe, who, following Carl Friedrich Phillip von Martius, in "Über die Spiraltendenz," in *Sämtliche Werke* (as in note 12), vol. 18.2, 480ff., speaks of the spiraling tendency as the productive principle of life (ibid., 482).

31 These morphological developments demanded philosophical admiration, the "deeply symbolic" primordial form of the egg being reflected in Egyptian and Greek mythology. Sphere and egg related like "zero and number," "fundamental ability and real action", see Carus 1861 (as in note 28), 47. Goethe made reference to Carus' description of the primordial shape of the sceleton as a "Hohlkugel-Schale," and to the egg-shaped "Urform der Weichtiere," which in the respective illustration is depicted as a sphere – similar to the primordial vertebra ("Urwirbel"), which he drew in globular shape: cf. Goethe's fragments on Carus' "Von den Ur-Teilen des Schalen- und Knochen-Gerüstes" and "Über die Urform der Schalen kopfloser und bauchförmiger Weichtiere", in *Sämtliche Werke* (as in note 12), vol. 12, 285ff. and 250ff.

32 Cf. Carus 1861 (as in note 28), 42.

33 Protoorganisms like these form a distinct realm of organism in between plants and animals, the "medium and original" realm of organisms: cf. Carl Gustav Carus, *Lebenserinnerungen und Denkwürdigkeiten (1865/66)* (Weimar: Kiepenheuer, 1966), 517.

34 The German phrase is a pun: "[...] hinter allem Sachlichen dem Ursachlichen nachzuspüren" (ibid., 174). The passage on the line seen through the microscope stems from a letter to Ida von Lüttichau (ibid., 86). In *Die Proportionslehre der menschlichen Gestalt, zum ersten Male morphologisch und physiologisch begründet* (Leipzig: Brockhaus, 1854), Carus argues in the psycho-aesthetic, physiognomic way that body and mind (and their interrelations) could be described in mathematical and geometrical terms. Round and square geometrical figures had

Nature observes itself: direct representation

According to romantic natural philosophy, observation of empirical objects could not guarantee true knowledge about nature. Still true knowledge was possible, substantiated by a structural isomorphism rooted in the analogy of micro- and macrocosm. Within this pattern of thought, the formation of organic bodies directly corresponded to cognitive processes. As Carus put it with Schelling in his *Grundzüge allgemeiner Naturbetrachtung*, the "zero" was the primordial unity of organisms as well as of ideas, divided into poles of "plus and minus."[35] All possible cognitive oppositions included in the initial unity could be uncovered by examination of the inherent polar structure of thoughts. The cognitive principles in man, the process of developing thoughts, concepts, and terms, equaled the universal principles of morphogenesis, since man was a microcosmic analogon to cosmic unity. The whole world a living organism, the aim of all scientific investigations was the recognition of nature's unity in its underlying idea. All scientific cognition therefore would have to move from the universal to the particular, from the "most simple to the most complex" and is hence labeled "organic cognition" ["organische Erkenntnis"].[36]

This concept of organic cognition implied the possibility of gaining knowledge about nature by means of an *intuitive, direct perception*, the observer and the observed based on the same structuring forms and following the same natural laws. As Karl Friedrich Burdach put it in his lecture *Über die Aufgabe der Morphologie*, "we are not blind products of structuring forces," but subjects and objects of life at the same time – "in us the world comes to self consciousness, to self intuition ['Selbstanschauung']:"

> *The unity at the basis of the phenomena lies in the essence of our reason, therefore, prior to and independent of all experience. Reason is precisely the point where nature grasps itself as*

their equivalents in human psychology: "round types" denoted the genius, since it was the form of life and the "Urform aller organischen Gestaltung." Square forms in contrast resembled crystals and pointed to active and energetic types.

35 Carl Gustav Carus, *Grundzüge allgemeiner Naturbetrachtung* (1823) (Darmstadt: Wissenschaftliche Buchgemeinschaft, 1954), 37. Older systems of classification were thus replaced by an "ideal-genetic" model, which tied change in nature to an ideal unity and a progressive movement from the universal to the particular.

36 Carl Gustav Carus, *Organon der Erkenntnis der Natur und des Geistes* (Leipzig: Brockhaus, 1856), xi. In his *System der Physiologie, Dritter Theil* (Dresden/Leipzig: Fleischer, 1840), 484, Carus further elaborates the development of "organic ideas" in connection with the polar division of a magnetic stick. In Carus 1861 (as in note 28), 55, he endorses Schelling's ideas: "Alle Bewegung und Thätigkeit, alle Lebensregung, auch die der Natur, ist nur ein bewußtloses Denken, oder geschieht in der Form des Denkens; je mehr aber in der Natur das gesetzmäßige sich zeigt, desto geistiger erscheint ihr Wirken. Die optischen Phänomene z.B. sind somit schon ganz eine Geometrie, deren Linien das Licht zieht, und eine vollendete Theorie der Natur (Naturphilosophie) würde diejenige sein, kraft welcher die ganze Natur in eine Intelligenz sich auflöste [...]," and also refers to Plato: "The permanently moved never dies [ist unsterblich]."

a whole, where being comes to the highest and truest consciousness of itself, where individual beings are raised to universal being and its innermost essence becomes objectified.[37]

With nature represented directly in human reason, truth is substantiated by man as an organism, his thoughts matching with the structures of nature, his intellectual intuition hence serving as a basis for scientific knowledge.[38] For Carus, it was the unifying cosmological principle of the sphere that not only connected the realms of human and natural development, but the perceived to perception: the "primordial idea" or "thought of God" pointed to an isomorphic relation of the harmonious household of nature and human perception.[39] Here Carus like other romantic naturalists followed the antique idea of *theoría tou kosmou*, denoting the unity of the divine, the natural and the rational.[40] Within this kind of reasoning, *mundus sensibilis* and *mundus intelligibilis* could be apprehended in one act of contemplation that bridged the gap between perception and comprehension. Neither was there a border between the true and the beautiful, between rational and aesthetic perception of nature: beautiful nature represented true nature, the harmony, purposefulness and order of which guided the eye of the beholder towards something that could not directly be observed. This "theoretical experience" aimed at knowledge of nature as a whole, not at individual and particular phenomena. As a "twofold perception," it transcended the sensorial world by a "leap from the visible to the invisible," as Ruth Groh has pointed out.[41] If "observation" is understood as a kind of selective perception,[42] based on

37 Karl Friedrich Burdach, *Über die Aufgabe der Morphologie* (Leipzig: Dyk, 1817), 7 and 19–21; cit. from Lenoir 1982 (as in note 13), 74; cf. ibid., 69, on the intuitive understanding of life as an activity that man according to romantic *Naturphilosophie* has as "the fullest expression of the unity at the basis of nature."

38 Dietrich von Engelhardt has pointed to this concept in Hegel and Schelling: "*Naturphilosophie* according to Schelling 'is nothing but physics, but it is only speculative physics.' The correctness of the philosophical constructions is demonstrated by the 'coincidence of the product appearing in experience with that which has been constructed'." Cf. Dietrich von Engelhardt, "Science, Society and Culture in the Romantic Naturforschung Around 1800," *Nature and Society in Historical Context*, ed. Mikulás Teich, Roy Porter, Bo Gustafsson (Cambridge et. al.: Cambridge Univ. Pr., 1997), 195–208, 196, citing F. W. J. Schelling, "Einleitung zu dem Entwurf eines Systems der Naturphilosophie" (1799), in Schelling 1927 (as in note 26), vol. II, 274; Schelling, "Ueber den wahren Begriff der Naturphilosophie" (1801), in Schelling 1927 (as in note 26), vol. IV, 30.

39 The "Urelement" is the ether, its primordial motion the motion of life: "Entstehen und Vergehen, Handeln und sich Verwandeln nach einer eingeborenen Idee, einem Gottesgedanken [...]" (Carus 1861 (as in note 28), 54); cf. ibidem., 136: "Es gibt keine andern menschlichen Werke, keine andern Werke der Kunst, als die mit den Werken der Natur nach ein und demselben Gesetze vonstatten gehen."

40 Cf. Ruth Groh, "Van Eyck's Rolin-Madonna as a Response to the Crisis of Medieval Universalism. An Approach from the Aesthetics of Nature" *Compar(a)ison* 2 (1998): 57–77, 60. Martin Seel, *Eine Ästhetik der Natur* (Frankfurt a.M.: Suhrkamp, 1991), 73 and 78, speaks of "metaphysics of contemplation," interpreting the contingent as revelation of the eternal.

41 Groh 1998 (as in note 40), 57.

42 Martin Mahner and Mario Bunge, *Foundations of Biophilosophy* (Berlin et.al.: Springer, 1997), 71.

a set of theoretical preconceptions about nature, *theoretical experience* of nature did not distinguish between perception and observation.

The idea of a direct perception of the hidden laws and ideal forms behind the surface of phenomena thus can be considered *intuitive knowledge*. Nature and knowledge based on the same structures and following the same formative laws, romantic naturalists like Carus, Johann Baptiste Spix, Karl Hinrich Lichtenstein, and others used circle diagrams as a classificatory schema, scientific representation being structured by poles, equators, meridians and latitudes: "Depicting the system of animals in circle diagrams and other harmonic geometrical figures corresponded to the natural philosophical striving to deduce mathematical laws, which sometimes met with 'Pythagorean mysticism of numbers'."[43] As the romantic philosopher Adam Müller pointed out: "All science has globular form."[44] Within the context of Müller's romantic morphology of human society, *the sphere*, equaling the absolute, equaling the archetype, could directly be grasped by aesthetic intuition, just like in Carus' organic cognition: the "spherical totality of economic objects" was symmetrically arranged like the different organs of the human body "in the eyes of the illustrator:"

> *Sobald aber die Verhältnisse der Dinge untereinander betrachtet werden, und diese Verhältnisse sich gleichfalls untereinander wieder zu größeren Verhältnissen gruppieren und fügen, gliederweis sich wie die Organe des menschlichen Körpers vor den Augen des Zeichners ordnen, und sich zuletzt eine unendliche Symmetrie, ein glückliches Gleichgewicht in allen*

43 Jahn 1989 (as in note 20), 297f.; Jahn hints to Carus' circle diagrams, wherein the variety of forms were thought to increase, the more remote the organism was to man. Johann Baptiste Spix (1815) relied on circle diagrams for classification, and so did Karl Hinrich Lichtenstein in a lecture in 1834/35. Zoologist F.F. Kaupp based his system on the number five and depicted it in form of a pentagram (1844), Georg August Goldfuss (1817) chose the form of an egg, within which 12 classes of animals are harmonically integrated. Ludwig Reichenbach followed Oken's quaternary system (1852), which could be found "within nature itself." Charles Darwin dealt with similar diagrams created by William Sharp MacLeay or Louis Agassiz.

44 Which is the "eternal scheme of all earthly matters and works for the Christian philosopher." Müller also followed Schelling's idea of polarity and conceived a general theory of oppositions within a spherical whole. He envisaged a "theory of the sphere" for the unfinished third book of his *Lehre vom Gegensatze*, to which he hints in the programmatic fragment from 1812, cited above: Adam Müller, *Vermischte Schriften* (Wien: Camesiner, 1812), vol.1, 378f. Müller alludes to the romantic "Bewußtseinstheologie" of Friedrich Schleiermacher, who saw a direct link between the individual consciousness and God, cf. Friedrich Schleiermacher, *Über die Religion: Reden an die Gebildeten unter ihren Verächtern* (Berlin: Unger, 1799). Man was thus able to intuitively grasp the whole of the universe, *to feel the infinite through the finite. Similarly, Müller* speaks of the man as susceptible to the "revelation" of the "whole of nature," which in its "holy, infinite motion is God", cf. Adam Müller, "Vorlesungen über das Schöne," *Phöbus. Ein Journal für die Kunst* 2 (1808): 35–42, 37, 41; 3 (1808): 3–20.

Teilen offenbart, dann ist ein deutliches Bild des Ganzen möglich, ein Bild, wo man mit den größeren
formt werden.[45]

It was as if the objects spoke for themselves, being self-evident in their harmonious geometrical form: the spherical arrangement triggered an *aesthetic* access to the inner "mathematical law of formation" underlying "all works of nature, art and civil society," and thus supported scientific knowledge.[46] Here again, Goethe's aesthetics of nature is evoked, since there was not only a "comfort in the internal regularity and consistency of nature,"[47] but geometry with Goethe was regarded "as the actual warrantor of this completeness [i.e. of science and aesthetic in the formative capacity] and of the satisfaction of science."[48]

Investigations into the realm of form that stood in opposition to romantic *Naturphilosophie* and instead followed in the "teleomechanical" tradition of Kant and Jakob Friedrich Fries, more clearly differentiated between scientific observation and aesthetic perception.[49] Approaches like that of Matthias Jacob Schleiden or Johannes Müller

45 Adam Müller, *Versuche einer neuen Theorie des Geldes* (1816), in *Nationalökonomische Schriften*, ed. Albert Josef Klein (Lörrach: Albert Kern, 1983), 76, alluding to Philipp Otto Runge, *Farbenkugel oder Construction der Verhältnisse der Farben* (Hamburg: Perthes, 1810). In his *Betrachtungen bey Göthes- und Runges-Farbentheorie*, in: *Ausgewählte Abhandlungen*, 387f., Müller proposes the idea that the color-sphere is the scheme of all moral and literary critique, depicted in Runge's order of all pure colors around the equator of a sphere and their tones up to the poles of pure white and black. On the spherical totality of economic objects and their development according to spherical harmonic order cf. Müller 1983 (as above), 205f. Similar to Müller, natural philosopher Henrik Steffens interpreted society and historical change in analogy to formative natural forces, cf. Engelhardt 1997 (as in note 38), 201.

46 Müller 1983 (as note 45), 144. On the self-evidence of geometrical shapes cf. Lorraine Daston, "Introduction," in Daston 2004 (as in note 25), 12.

47 Goethe in 1807 wrote in his notebook: "Trost in der innern Regelmäßigkeit und Konsequenz der Natur." Cf. *Werke* (as in note 9), vol. XVII, 626, vol. XVIII, 1135; cf. Hans Blumenberg, *Die Lesbarkeit der Welt* (Frankfurt a.M.: Suhrkamp, 1986), 227.

48 Müller 1983 (as in note 45), 252: "Wenn daher einige wenige größere Seelen für die Wissenschaft die künstlerische Form reklamiert haben, so haben sie damit etwas viel Höheres als die äußere Geschliffenheit oder die Eleganz des Gewandes gemeint. Sie haben das zum Denken so gut als zum Dichten unentbehrliche bildende Vermögen zurückverlangt; und meine Elemente der Mathematik werden auf unüberwindliche Weise zeigen, daß die Geometrie der eigentliche Bürge dieser Vollständigkeit und Befriedigung der Wissenschaft sei."

49 On the teleomechanical tradition in biology cf. Lenoir, Strategy of Life, and the critical appraisal in Robert J. Richards, *The Romantic Conception of Life. Science and Philosophy in the Age of Goethe* (Chicago and London: Chicago University Press, 2002), 227–229. Matthias Jacob Schleiden, *Schelling's und Hegel's Verhältniss zur Naturwissenschaft* (Leipzig: Wilhelm Engelmann, 1844), and idem, *Grundzügen der wissenschaftlichen Botanik* (Leipzig: Wilhelm Engelmann, 1849), 7f., 18f., refers to the "Kantisch-Friesische" tradition as opposed to that of Hegel and Schelling. Thomas Broman, "University Reform in Medical Thought at the End of the Eighteenth Century", Osiris, 2nd Series, vol. 5: Science in Germany: The Intersection of Institutional and Intellectual Issues (1989): 36–53, 42, points out that Kant's *Critique of Pure Reason* in this context was read as a book about the possibility of scientific knowledge: ideal science was "one

did not strive to discover absolute meaning or platonic entities behind a given number of individuals. Understood as something "*transphenomenal*,"[50] common types did not have to be true to nature in the sense of identity to the absolute. If they merely denoted something universal that could rationally be inferred from a given series of observed individual objects, being true to nature required only coherence with the universal laws and forms that govern nature; this implied accurate observation of nature, since the exploration of the general started off with the particular phenomena.

Still even for those who favored *observation*, aesthetical perception played a crucial role. As most naturalists of the first half of the nineteenth century expressed their uneasiness about the increasing specialization and splintering of the sciences, the appeal to aesthetics of nature was rendered important as a *complementary approach* to a tendency of singularization. Aesthetics provided a way to safeguard the investigation of empirical particulars within a comprising whole, aesthetic perception balancing scientific observation. Thus, many authors referred to Alexander von Humboldt's invitation to search for the "living whole," for "unity in diversity" and to try to grasp "the spirit of nature hidden underneath the cover of apparitions."[51] Goethe argued for a mutual interdependence of analysis and synthesis, which were like "breathing out and breathing in,"[52] whilst Johannes Müller confirmed that scientific investigation had to be based on the principle of "denkende Erfahrung,"[53] and Matthias Jacob Schleiden likewise stressed the limits of empirical investigations:

> *Wenn wir mit unseren Beobachtungen und Experimenten, mit Zergliederungen, Schlüssen und Beweisen uns die Natur in ein plan verständliches Gewebe von Stoffen und Kräften*

that contained a limited number of fundamental statements by which empirical data could be logically organized and understood. Those fundamental statements would themselves be based on the structures of knowledge in general, on the very conditions that constituted the possibility of knowledge."

50 Mahner/Bunge 1997 (as in note 42), 72. Cf. Engelhardt 1997 (as in note 38), 198: "The interpretations of nature were guided by metaphysical and mathematical principles, by formal categories like differences and identity, analogy, polarity, potency and metamorphosis, but also by specific phenomena and processes of particular spheres of nature. All philosophical understanding must depend on science, on empirical facts."

51 Alexander von Humboldt, *Kosmos. Entwurf einer physischen Weltbeschreibung* (4 vols., Stuttgart: Cotta, 1844), vol. 1, 5.

52 Johann Wolfgang von Goethe, "Erläuterungen zu dem aphoristischen Aufsatz 'Die Natur'," in *Goethes Werke*, ed. Erich Trunz (Hamburger Ausgabe) (14 Vols., München: C. H. Beck, 1998), vol. XIII, 48–52, 51; cf. "Morphologie" [1817], in: ibid., 53–250, 55. In "Erfahrung und Wissenschaft," in: ibid., 23–45, Goethe distinguishes between empirical, scientific and pure phenomena, and points to the relation between analysis and synthesis (ibid., 27): "Die Erkenntnisse a priori ließ ich mir [...] gefallen, so wie die synthetischen Urteile a priori: denn war ich doch in meinem ganzen Leben, dichtend und beobachtend, synthetisch, und dann wieder analytisch verfahren, die Systole und Diastole des menschlichen Geistes war mir, wie ein zweites Atemholen, niemals getrennt, immer pulsierend."

53 Cf. Johannes Müller, *Handbuch der Physiologie des Menschen für Vorlesungen* (2 vols., Koblenz: Hölscher, 1837–40); idem, *Von dem Bedürfnis der Physiologie nach einer philosophischen Naturbetrachtung. Eine öffentliche Vorlesung, gehalten zu Bonn am 19. Oktober 1824* (Bonn 1825).

> *zerfasert haben, treten uns die Schönheit und Erhabenheit derselben dazwischen, verknüpfen das Zerlegte wieder zu einem einigen Ganzen und spotten unserer Bemühungen das ewig Unbegreifliche begreifen zu wollen. Wir erklären's nicht und doch ist es wahr, wir begreifen's nicht und doch ist es da.*[54]

What these authors referred to were not ideal types in the platonic sense. Rather, it was the geometrical appeal to universality of simple forms that shaped their attitude towards nature. The alleged geometrical structure of nature formed a basis for the assumption of a development from simple to complex organisms, it hinted towards architectural principles in the realm of life. Schleiden in his *Grundzüge der wissenschaftlichen Botanik* (1842) stressed that the mathematical philosophy of nature provided universal principles for usage of induction. Nevertheless comparisons between parts of plants and geometrical figures did "not go far," and "regular mathematical shapes never occur in plants" – "except for the globular form of the single cell."[55]

To Schleiden, scientific knowledge had to be based on either experiment or observation, which again had to be carefully trained in order to devote attention to the relevant details in nature. In his chapter on the usage of the microscope, he emphasized that "the impartiality of the observer not at all acquainted with botanic theories" *did not* guarantee for the correctness of his representation of nature. A skillful use of the instrument as well as experience with natural objects was absolutely essential, following the rule that "to be a lucky observer, one has to observe with intense attention, to gradually learn to see, since seeing is a difficult art."[56] Only in this way could scientific drawings be "true copies of nature."[57] While *Naturphilosophie* had abstracted from irrelevant details in order to gain knowledge of ideal types, Schleiden emphasized the necessity of training the attention in order to closely observe exactly these details – small, but relevant parts of the object. He could only control the plenitude of details that the microscope revealed to him by deliberately directing his visual attention to particular sections of the object displayed.[58] Skills like these were still relevant for Nägeli and Schwendener twenty years later. For them and other microscopists, to be true to nature no longer required the representation of nature *as it is*, but merely an approximation as close as possible. Objectivity had changed sides, was not to be found in nature itself but in skilled observation, scientif-

54 Matthias Jacob Schleiden, *Die Pflanze und ihr Leben. Populäre Vorträge. Mit 5 farbigen Tafeln und 13 Holzschnitten* (Leipzig: W. Engelmann, 1848), 287.

55 Matthias Jacob Schleiden, *Grundzüge der wissenschaftlichen Botanik* (2 vols., Leipzig: Wilhelm Engelmann, 1842), I, 140; II, 7f., 16.

56 Ibid., I, 121; on impartiality and skills 105f., 197.

57 Ibid., I, 123.

58 This fits in with Jonathan Crary's thesis about the mid-nineteenth century break of regimes of observation, cf. Jonathan Crary, *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* (Cambridge Mass.: MIT Press, 1991); idem, *Suspensions of Perception: Attention, Spectacle, and Modern Culture* (Cambridge Mass./London: MIT Pr., 1999).

ic conventions on representation, and connoisseurship in the handling of technical devices for each particular case.[59]

At the same time their contemporary, zoologist Ernst Haeckel, provided an allegedly new – evolutionary – perspective on morphology that followed traditional accounts of the visualization of nature: instead of pleading for accuracy like his colleagues, he represented ideal natural forms by omitting irrelevant details; instead of arguing for intersubjective standards rather than natural truths,[60] he insisted on the objective prototypical character of abstractions from reality.[61] In his system of promorphology, Haeckel presented perfect geometrical shapes, *evolutionary* archetypes, the first organisms on earth, from which all other forms of life gradually emerged. Concerning the causes for this morphogenetic perfection, he polemically opposed Nägeli's vitalistic reference to an immanent morphogenetic force of nature, this being a sign of intellectual regress to mystical dualistic metaphysics or even to the idea of a divine architect.[62] Nevertheless, he not only conceived an *aesthetic natural law* responsible for the beauty of nature, inferred from the stereometric shape of organisms and an alleged universal progression towards more complexity, harmony and order[63] – he himself had held clearly physicotheological posi-

59 Nägeli/Schwendener 1867 (as in note 1), 284: "Man kann billiger Weise nicht verlangen, dass die Hand des Zeichners richtig darstelle, was das Auge des Beobachters unrichtig gesehen hat. Die Anforderungen, die man gewöhnlich an den Zeichner zu stellen pflegt: richtige Auffassung, Verständnis des Gegenstandes, Naturwahrheit ohne Subjektivität etc. müssen demnach streng genommen auf den Beobachter bezogen werden; der Zeichner hat bloß die Aufgabe, die Vorstellung, welcher der Beobachter sich angeeignet hat, sie mag nun richtig oder unrichtig sein, in Anderen wieder zu erwecken." Hugo von Mohl, *Mikrographie oder Anleitung zur Kenntnis und zum Gebrauch des Mikroskops* (Tübingen: L.F. Fues, 1848), 250, emphasized that skills had to be learned by demonstration and frequent use of the microscope and pointed to dexterity (255), and the necessity of training the eye in order to correctly direct the attention (ibid., 264–267). The scientist himself, even if not a skillful artist, should draw his objects, since he was less likely to overlook relevant details; he thus needs mechanical helping devices like the *camera lucida* (ibid., 321f.).

60 The key to correct representation lies in the beholder: It is uniformity in representation, not in the object, which anyway can only be observed from different angles, see Nägeli/Schwendener 1867 (as in note 1), 289f.

61 Cf. Martin J. S. Rudwick, "The emergence of a visual language for geological science, 1760–1840," *History of Science* 14 (1979): 149–95. Rudwick explains the emergence of visual language for geological sciences as a part of a general increase of visual communication in the sciences, and a development towards more abstraction and formalization (diagrammatic illustrations), capturing the increasing load of theoretical meaning (ibid., 177f.).

62 Cf. Ernst Haeckel, *Die Lebenswunder. Gemeinverständliche Studien über Biologische Philosophie. Ergänzungsband zu dem Buche über die Welträtsel* (Stuttgart: Kröner, 1904), 207.

63 By referring to Darwinism as the pinnacle of modern science, he staged a new basis for aesthetics of nature, maintaining the idea of nature as an artist. On the one hand, nature could again be seen as a whole, as all phenomena had to be regarded as individual realizations of a unified process. Man, being but a part of nature, not only intuitively followed the same laws when creating art – his cognition of nature had developed in permanent reference to his environment. Thus, in the course of evolution an a priori knowledge had been formed, increased and transmitted that compensated all the insecurities of subjective sensual perception: in direct observation, man could intuitively grasp the truth as well as the beauty of na-

tions up to the 1860s, especially when referring to microorganisms and the "greatest marvel of creation," the cell.[64] Beauty to Haeckel lay in the geometrical shapes of the observed items, with the filigree-like structures of marine microorganisms as an exemplary representation of the artistry of nature. Especially spherical entities served as a reference for the wholeness of nature, depicting the microcosmic analogy to cosmic harmony. Obviously, concepts on the inherent beauty of nature not only became the foundation for evolutionary ethics and aesthetics – the romantic idea of direct perception was transformed to evolutionary epistemology, the positive selection of true knowledge. Here, science could observe how man, representing ideal nature, directly perceived what science observed.

ture. He automatically followed the same formative principles when creating art, and as art had a complementary role to science, scientific illustrations necessarily had to depict these principles, even if this would end up to an idealization of the object under consideration. Cf. Bernhard Kleeberg, *Theophysis. Ernst Haeckels Philosophie des Naturganzen* (Köln/Weimar: Böhlau, 2005).

64 Cf. Ernst Haeckel, *Entwicklungsgeschichte einer Jugend. Briefe an die Eltern 1852/1856*, ed. H. Schmidt (Leipzig: Koehler, 1921), 88–90, and 131f.