Peter McLaughlin

Blumenbach and the Formative Drive*

On the relation of epigenetic embryology to a typological species concept

> Speciem ergo in qualitatibus materiae vegetabilis consistere concludimus, non in formis.
> (C. F. Wolff)

Nearly 16000 years ago on Jupiter's third moon, elephants arose by spontaneous generation – at least this is what Buffon thought shortly before the French Revolution. On the question of the relation of epigenesis to species concepts in the natural history of the later eighteenth century we should remember that we are dealing with a species concept that is able to comprehend these hypothetical inhabitants of the celestial bodies as real conspecifics of our local proboscideans. The following considerations are based on the thesis that the epigenetic concept of species is essentially ambiguous: The epigeneticists understand the biological species on the one hand as a historical lineage of descent, an empirically given population that reproduces itself in time, and on the other hand as the realization of a type that is in the last analysis the necessary consequence of the structural properties of matter. Their explanation of the development of the individual (epigenesis) presupposes a concept of species which excludes the development of the species itself. This can be shown in Buffon's mechanistic theory and C.F. Wolff's "chemistic" theory. I would like here to try to explicate the thesis on the basis of J.F. Blumenbach's *vitalistic* theory of epigenesis.

1 Vitalism

Johann Friedrich Blumenbach (1752–1840), said Lorenz Oken in 1805, "was the first and only one, who with courage and spirit confronted the crude mechanism that ... had penetrated physiology, and, although it had everywhere taken firm root, yet eradicated it root and branch." [1] Blumenbach's writings can serve not only to trace the transition from mechanism to vitalism in emerging biology in Germany, but also to identify the scientific problems that determined this transition. Blumenbach is particularly suitable for this purpose because he (like Schelling) documented his scientific education in public,[2] and because he can be considered representative for the development of biology in Germany in two respects: as an "institution" and as a theoretician.

1) As a professor of medicine, Blumenbach taught physiology and natural history in Göttingen for more than 50 years. Blumenbach and his immediate students educated three generations of

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[1] Lonrenz Oken: *Die Zeugung*, Bamberg and Würzburg 1805, p. 101.

[2] The development can be traced most easily by the various editions of his popular scientific *Handbook of Natural History*: *Handbuch der Naturgeschichte*, Göttingen: Dietrich, 1779/80 (2nd ed. 1782; 3rd ed. 1788; 4th ed. 1791; 5th ed. 1797; 6th ed. 1799; 7th–12th eds. 1803, 1807, 1814, 1821, 1825, 1830).

naturalists. Among his students and disciples were such influential researchers as Kielmeyer, Link, Treviranus, Oken, Girtanner, Humboldt and others.

2) With the theory of the "formative drive" (*Bildungstrieb*) Blumenbach established a principle that could connect embryology and physiology with natural history, i.e., the system level of the *organization* of the individual with that of the *order* of animate nature.[3] The unification of these two system levels under a unified principle facilitated the transfer of the analytical methods of physiology to the hitherto mostly merely descriptive and classificatory natural history – a transfer that was a prerequisite of a unified *science* of life, biology. Blumenbach's work brings together three traditions of biological research: Haller's physiology, Linné's systematics, and Buffon's claim to causal-analytical explanation in natural history.

The theory of the formative drive, through which Blumenbach sought to explain both the expression of form in the individual and the distribution of forms among species, is generally regarded as vitalism. But since there is hardly any agreement about what is to be understood by this term, I shall introduce some considerations that make it clear how the term is used here.

According to Hans Driesch[4] vitalism is a theory that ascribes to life processes an "autonomy" that cannot be reduced to "a particular constellation of factors." Although Driesch wants to trace vitalism back to Aristotle, he admits that in Blumenbach vitalism takes on a new quality. I think it would be more accurate to say: this is the time that vitalism first emerges.

The theoretical current to which I want to limit this term arose in the second half of the eighteenth century in embryology and physiology in opposition to the prevailing mechanism and as a successor to the no longer viable animism. Its emergence can be located in the school of Montpellier in France,[5] with Bocklesby and Hunter in England,[6] and with Blumenbach in Germany. In all three cases its point of departure is the theory of irritability of Albrecht von Haller. The earlier animism had tried to explain the particularity of the organic by assuming an animal or vegetable soul or form. Mechanism, which had been gaining ground since Descartes and Borelli, explained life through organization (or the form of organization). That life is a mechanical result of the organization of matter, is asserted accordingly by La Mettrie, Buffon and Holbach. Albrecht von Haller's experiments had shown that an important property of at least animal life, namely irritability, belongs to the muscle fibers, even if they are separated from the body and thus cannot be under the influence of the soul, unless that soul were divisible, i.e., material. However, these experiments were also the undoing of mechanism, in that they were generally interpreted as showing that the irritable property of a bodily element was independent of the bodily system, thus also of the organization of the animal. Even though Haller himself remained a mechanist, he laid the foundation of vitalism,[7] by seeking the explanation of life below the level of the individual organism.

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[3] On the concepts *order* and *organization*, see H.-J. Rheinberger, "Über Formen und Gründe der Historisierung biologischer Modelle von Ordnung und Organisation am Ausgang des 18. Jahrhunderts," in: M. Hahn/H. J. Sandkühler (eds.): *Gesellschaftliche Bewegung und Naturprozess*, Cologne, 1981

[4] Hans Driesch, Der Vitalismus als Geschichte und als Lehre, Leipzig, 1905, p. 1.

[5] See J. Schiller, "Queries, Answers and Unsolved Problems in Eighteenth Century Biology," *History of Science 12* (1974), pp. 184–199.

[6] See T. M. Brown, "From Mechanism to Vitalism in Eighteenth Century English Physiology," *Journal of the History of Biology 7* (1974), pp. 179–216.

[7] See Richard Toellner, *Albrecht von Haller. über die Einheit im Denken des letzten Universalgelehrten*, Wiesbaden, 1971; and "Mechanismus – Vitalismus: Ein Paradigmawechsel? Testfall Haller," in: Alvin Diemer (ed.)

While animism and mechanism started from the organic form and explained the functioning of organic matter by an immaterial or material-inorganic force that depended on this form, vitalism – as we will see on the example of Blumenbach – tried to explain organic *form* by organic *matter*. Vitalism asserts that there is a special kind of causality in organic matter, an *organic force*. 'Organic force' here means a force that *acts* only in organic matter, not a force that *causes* the transition from inorganic to organic matter. The latter, whether conceived materially or immaterially, would in any case be an *inorganic*, albeit organic-making force. John Hunter said in 1770:

> Animal and vegetable substances differ from common matter in having a power *superadded* totally different from any other known property of matter, out of which arise various new properties; it cannot arise out of any peculiar modification of matter, but appears to be something *superadded*…. Organization may arise out of living parts, and produce action; but life can never arise out of and depend upon organization…. Organization and life are two different things.[8]

This vitalism does not explain life, it presupposes it unexplained or as inexplicable. When asking about the cause of life or the vital force, a comparison with the *cause* of Newton's gravitational force was common at this time. This is more than just a phrase; the vitalists of the late eighteenth century were Newtonians. Their vitalism was the old mechanism plus "something superadded," namely a vital force.[9]

A perhaps accidental occasion of the emergence of vitalism, but not without significance for the history of science, can also be taken from a remark by Driesch. He says, "the development of form, however, is the actual ground of vitalism, from it alone does it really draw its powers";[10] and he points in particular to the phenomenon of *regeneration*. The experimental investigation and the explanation of the regeneration capabilities of the polyp formed the starting point of Blumenbach's epigenesis theory and vitalism.

2 The concept of species

In order to characterize Blumenbach's concept of species, it is perhaps useful to point out a conceptual difference that was mostly overlooked in the debates of the time. I want to distinguish between the concept and the distinguishing criterion of biological species. The concept tells us what a state of affairs is; the decision criterion tells us how to tell whether the state of affairs is given or not. Buffon, for example, conceives of the species as a lineage, a tribe. His decision criterion on whether two given individuals belong to the same species whether they are be able to mate and produce *fertile* offspring. If there are fertile offspring, then one knows that the two parents are members of the same species and share a common ancestry.

Buffon's criterion for decision, however, is not an arbitrary feature such as the number or location of stamina and pistils in Linné's artificial system. The species is not simply a collection

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Die Struktur wissenschaftlicher Revolutionen und die Geschichte der Wissenschaften, Meisenheim, 1977, pp. 61–72.

[8] Quoted from June Goodfield/Stephen Toulmin, *The Architecture of Matter*, University of Chicago Press, 1962, p. 323. [See *The Works of John Hunter, F.R.S.,* vol.1, James F. Palmer (ed.) London: Longman,et.al., 1835, pp. 214, 221, 242]

[9] On vitalism as Newtonianism in biology, see below, Section 4, and H.-J. Rheinberger, "Zur Herausbildung und Problematik Zur Herausbildung und Problematik des wissenschaftlichen Begriffs der Entwicklung in Natur- und Menschengeschichte," in: P. Furth (ed.): *Arbeit und Reflexion*, Cologne: Köln: Pahl-Rugenstein, 1980, pp. 144–158.

[10] H. Driesch, *Vitalism* (see note 4), p. 133.

of individuals similar enough to each other to mate; it is a physical process mediated by procreation. Fecundity is the result of common descent and is a condition for the continued existence of the lineage. Thus, there is a physical connection between fertility and common descent; however, one does not necessarily imply the other. The possibility that animals which do not produce fertile offspring with each other (such as horse and donkey) may yet be of common descent is conceded by Buffon; but he claims that the physical probability is so small that this possibility must be discarded.[11]

Although Blumenbach's "natural system" (or as he later says, "more natural system" or "so-called natural system") owes much to Linné's artificial system, there are major differences in method and ontology. Linné inferred from the similarity of some features a kind of natural similarity of whole organisms by means of which individuals could be assigned to real species, species to real genera, genera to real orders, and so on. Blumenbach, following Buffon, makes an ontological distinction between species and genus, between *Gattung* and *Geschlecht*: "Species are created by nature: the systematist places them under genera according to their common similarities."[12] But more importantly, he follows Buffon in his claim to causal explanation of the natural order. Blumenbach infers from the similarity of a set of pragmatically chosen characteristics (the so-called "overall habitus") the similarity of the *cause* of that habitus or organizational form.

Blumenbach makes a clear distinction between his "natural system" and the order of nature. The so-called chain of being is useful in constructing a systematics of species, but the real order of nature is ecological. An organism's place in the natural order depends not on its appearance but on its function – or as Blumenbach says, its "assignment" (*Bestimmung*). The real chain of being is a food chain or a causal chain rather than a chain of similarity.[13] Thus, the classification of individuals into species has a basis in nature. The ordering of classification units does not map the order of nature, but at best the similarity of the causes of the units of classification.

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[11] See Georges-Louis Leclerc, Comte de Buffon, "L'Asne" (1753) in: *Histoire naturelle, générale et particuliére, avec la description du Cabinet du Roy*, vol. 4. Paris: Imprimerie Royale, 377–8; see also P. McLaughlin: *Mechanismus und Teleologie in der Naturphilosophie Buffons*, Masters thesis in Philosophy at the Free University of Berlin 1979.

[12] J. F. Blumenbach, *Handbuch der Naturgeschichte*, 5th ed. Göttingen: Dietrich, 1797, preface.

[13] *Handbuch der Naturgeschichte* (1st ed., 1779), §7: "We would smile if someone were to seek the merit in the arrangement/furnishing of a house in the fact that the furniture in it was all of different shapes and sizes and could be brought into a smooth gradation like the purported chain of natural bodies. The perfection of the great economy of Mother Nature, just like the smallest economy of a family, is to be sought in quite different merits. That God in his creation has left no gaps, that this immeasurable clockwork nowhere falters but is conserved in uninterrupted motion and constant equilibrium, the reason for this will hardly lie in the fact that the orangutan makes the transition from man to ape, or that birds are to be connected with quadrupeds by way of the bats and with fish by way of the flying fishes: but rather that every created being has its assignment and the bodily structure needed for that assignment; that there is no purposeless creature, that does not make its contribution to the perfection of the whole. This secures that creation goes its way and that no wise man of any time or people has ever been able to find a gap in it. We do not seek a chain of nature, in the graded formation of natural bodies, nor in the fact that the one supposedly joins animals and plants and the other plants and stones; but in the designated tasks of the links of this chain, where one link interlocks with another link not according to its form, but according to its assignment etc. In the eternal circle of immeasurably wise arrangement, where the plants draw their nourishment from the earth, and afterwards serve men and animals as nourishment, and also one animal the another, and where in the end men and animals and plants become earth again; in this great circle *reason* need not presuppose any connecting links that would have to join these creatures of such different kinds in regard to their formation; just as experience has so far not shown us any natural bodies that could rightly lay claim to the name of such connecting links between the *three kingdoms of nature*."

Organisms, says Blumenbach, are different from inorganic bodies, because they "are produced by other natural bodies of the same shape and kind; so that their existence in an uninterrupted series up to the first creation always presupposes similar bodies, to which they owe their existence."[14] (In a footnote he adds: "or at least up to their first progenitors.") The species or genus is thus a line of descent, a tribe of related individuals reproducing identically in the course of history. Blumenbach calls the biological species mostly "genus" (Gattung) because "nature shows (*at least in the ordinary course*, *de regula*) that only the animals of one *species* mate (*gatten*) with each other"[15]

Although his concept of species is similar (if not identical) to Buffon's, he rejects the criterion of decision, fertility, which has been in use since Buffon. To determine to which species an organism belongs, he chooses morphological criteria, because he sees theoretical and pragmatic difficulties with mating attempts. On the one hand, he points out the pragmatic difficulty of mating, for example, elephants from Africa with elephants from Asia, especially because elephants in captivity are infertile anyway. On the other hand, he says, there are many animals that never mate in the wild but can be forced to mate by humans; he then wonders whether one should make one's assignments of individuals to species based on the rule or on the exception. Mating experiments are not good as experiments because they do not reveal the real (ordinary) processes of nature, but rather disguise them. Some animals, which can mate under "unnatural" conditions and produce fertile offspring, show such morphological differences that a common descent is not conceivable ("such a constant striking difference…, which cannot possibly be conceived as a mere consequence of degeneration."[16]) Blumenbach considers comparative morphological studies (especially of the internal structure) as a more reliable method to justify conclusions on a common descent. Blumenbach's rejection of Buffon's fecundity criterion is thus based precisely on Buffon's concept of species as a line of descent (a concept that he does not seem to have seen in Buffon, however).[17]

But Buffon's concept of species also included a causal explanation of the existence and nature of species. For him, species were empirical representatives of possible organizational forms of matter or "internal moulds" (*moules intérieurs*), and they arise spontaneously if need be. Blumenbach does not follow Buffon in his explanation of species, but he does in his claim to causal explanation. His alternative to Buffon's mechanistic *moule* is the vitalistic *Bildungstrieb*.

3. The Formative Drive

Blumenbach, who until 1779 had been a doubting adherent of Haller's preformation theory, switched to the epigenesis theory in 1780 with the introduction of the *Bildungstrieb* and in the course of the next ten years pursued the transition to vitalism. His systematic remarks on the nature of the formative drive are so brief that they can be quoted in full:

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[14] *Handbuch*, 4th ed., 1791, §2.

[15] *Handbuch*, 4th ed., 1791, Preface (emphasis P. M.).

[16] *Handbuch*, 6th ed., 1799, §14.

[17] *Handbuch*, 6th ed., 1799, §§10–14; B*eyträge zur Naturgeschichte*, vol. 1, Göttingen: Dietrich, 1790 (2nd ed., 1806), ch. 7; and "Über Menschen-Racen und Schweine-Racen," *Magazin für das Neueste aus der Physik und Naturgeschichte 6,* No. 1 (1789) 1–13. A different interpretation of the relationship between Buffon and Blumenbach can be found in Phillip Sloan: "Buffon, German Biology, and the Historical Interpretation of Biological Species," *British Journal for the History of Science 12* (1979) 109–153.

> That no preformed germs pre-exist: but that in the previously *raw unformed* matter of generation of organized bodies, after it has reached its *maturity* and its place of its destination, a special, then lifelong active drive is *excited* to take on its determinate form at first, then to maintain it throughout life, and if it has been mutilated, to restore it where possible.
> A drive, which therefore belongs to the *life forces,* but which is just as clearly different from the other kinds of life force of organized bodies (contractibility, irritability, sensitivity, etc.) as from the universal physical forces the bodies as such; which seems to be the first, most important force for all generation, nourishment, and reproduction, and which, in order to distinguish it *from other life forces*, can be designated by the name, formative drive (*nisus formativus*).[18]

What exactly this is supposed to mean is nowhere systematically further explicated. The formative drive is a force that brings about the effect. We do not know the cause of this force any more than we know the cause of gravitation; but it is a force "whose constant effect has been recognized from experience."[19]

Since the formative drive occupies a central place in Blumenbach's work, however, much about this theory can be reconstructed in the context of a systematizing interpretation. Information about the formative drive can be obtained from three sources: (1) from the differentiation from and comparison with other theories or forces; (2) from the determination of the regularities of its action; and (3) from the use of this principle in other contexts to explain other phenomena.

But already from this quotation some things are clear: Blumenbach's theory of the formative drive is not a theory of heredity and also not a theory of generation in the proper sense. As a contemporary critic aptly remarked, the formative drive occurs only "when conception, the actual generation, is already over."[20] It becomes "active" only after some time. Before this "maturity" is reached, the matter of generation is "raw" and "unformed," that is, *inorganic*. It is important to emphasize that the formative drive is not *caused* by this maturation process, but is *excited*. The transition from the inorganic to the organic (i.e., spontaneous generation in the proper sense) is the precondition and occasion for the excitation of the formative drive, which "belongs to the life forces" in the sense explained at the beginning.

(1) Let us now begin with what the formative drive is not: In the 1780s in the first formulations of the theory Blumenbach distinguishes the formative drive from other "forces of *nature*" and tries to make it plausible by its relationship to other formative forces of nature, which act, for example, in crystallization or in the formation of clouds. In more mature formulations, he distinguishes it from other "life forces" and denies all direct relationship with formative forces in inorganic matter (although an *analogy* still exists). These two formulations mark the beginning and conclusion of the transition to vitalism.

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[18] *Über den Bildungstrieb*, Göttingen 1789: Dietrich, pp. 24–25 (emphasis P. M.). Blumenbach "Über den Bildungstrieb (nisus formativus) und seinen Einfluß auf die Generation und Reproduction," *Göttingisches Magazin der Wissenschaften und Litteratur 1*, No. 5 (1780) 247–266; and "Über eine ungemein einfache Fortpflanzungsart." *Gött. Mag. 2,* No. 1 (1781) 80–89. With some additions, these two essays were then published as a book: *Über den Bildungstrieb und das Zeugungsgeschäft*, Göttingen: Dietrich, 1781. Blumenbach could not decide whether the 1789 work was a second edition or was intended to be a second book. In any case, he asks that the 1789 work "not be confused with the immature treatise that appeared under a similar title in 1781" (*Handbuch*, 4th ed. 1791, p.13)

[19] *Bildungsstrieb*, 1789, p. 26.

[20] Benedict Hösch: *Versuch einer neuen Zeugungstheorie*, Lemgo 1801, p. 57.

This transition can be illustrated by comparing the corresponding passages in the third (1788) and fourth (1791) editions of his *Handbuch der Naturgeschichte*.[21]

> On the other hand, the most unmistakable traces of an *almost* universally widespread drive to give matter a definite formation show themselves through the whole of nature; (*which is of striking effectivity even in the unorganized realm* …);
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> On the other hand, the most unmistakable traces of a universally widespread drive to give matter a certain formation show themselves through *the whole of organized nature*. [The remark in parentheses was deleted in the 4th edition.]

An *almost* universal force in the *whole* of nature has become a *completely* universal force, which however works *only* in organic nature. In his early formulations Blumenbach had also made vague hints about "fermentation or putrefaction" as a possible cause.[22] But in later writings Blumenbach (quoting Newton) does not feign hypotheses about the cause of the formative drive. At the end of the 1780s, Blumenbach explicitly acknowledges the qualitative leap between organic and inorganic matter ("One cannot be more intimately convinced of something than I am of the mighty gulf that nature has fixed between animate and inanimate creation, between the organized and inorganic creatures."[23] The formative drive, however, is not the *cause* of this leap, but its *expression*.

Blumenbach distinguishes his formative drive from various other presumed forces – especially from C. F. Wolff's "essential force." He makes it clear that his formative drive is not to be confused with Wolff's essential force, although – as he says – it is a force "whose reliable efficacy, however, I fully subscribe to from many years of conviction in a hundredfold observations of nature."[24] The essential force is "indeed a prerequisite *for* the formative drive – but by far not the formative drive itself."[25] Wolff introduced the essential force as *part* of an explanation of the epigenetic development of organic form, and Blumenbach is perhaps the only researcher of the time who recognized the limited nature of this force meant by Wolff: "To him, his *vis essentialis* is merely that force by which the nutritive substance is driven through the plant or animal."[26]

Wolff's essential force was a *chemical* attractive and repulsive force. The particles of the matter are not only differently formed, they have different chemical qualities and corresponding affinities. Thus, matter is qualitatively heterogeneous. The process of formation is *driven* by chemical attraction and repulsion; it is *directed* by the mechanical properties of the parts through which the supplied particles are driven, in a kind of chain reaction where one organ, by virtue of its mechanical-chemical nature, secretes the next, which in turn can do nothing but secrete the next, and so on – a process that Wolff calls a "system of changes."[27] It is important

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[21] *Handbuch*, 3rd, 4th and 5th eds, §9; cf. also §7; (emphasis, P. M.). A different interpretation of Blumenbach's development can be found in Timothy Lenoir, "Kant, Blumenbach, and Vital Materialism in German Biology," *ISIS 71* (1980) 77–108.

[22] *Bildungstrieb*, 1781, §12 (p. 23).

[23] *Bildungstrieb*, 1789, p. 71.

[24] *Über die Nutritionskraft* (§14) in: *Zwo Abhandlungen über die Nutritionskraft, welche von der Kayserlichen Academie der Wissenschaften in St. Petersburg den Preis getheilt erhalten haben. Nebst einer fernern Erläuterung eben derselben Materie von C. F. Wolff*, Petersburg: Kaiserliche Akademie der Wissenschaften, 1789.

[25] *Bildungstrieb*, 1789, p. 31 (emphasis by Blumenbach).

[26] *Bildungstrieb*, 1789, p. 31.

[27] Caspar Friedrich Wolff: *Theorie von der Generation*, Berlin, 1764 "From this you see how in animals the whole formation of the body gradually takes place, how one part after the other is brought forth, how one part secretes or deposits the other" (§74, p. 220). "One must regard the whole set-up for bringing forth new parts that exist on their

to note that the *direction* of development is determined by the circumstances in which the essential force operates, and that the supply of nourishment is necessary for development to occur.

Although Wolff's theory might have satisfied as an explanation of growth and even generation, the phenomenon Blumenbach attempted to explain and then generalized to other processses was not growth but the regeneration (or as he says "reproduction") of lost or mutilated parts. And this regeneration can take place without the supply of new matter. To take up Blumenbach's favorite example, if you cut your polyp longitudinally (instead of transversely) and then spread it out, it will roll up again or it will inflate and form a new abdominal cavity. Thus, Blumenbach concludes: "In these two cases mentioned and many others, no *new material* needs to be produced at all, – but only the destroyed *formation needs to be restored*."[28] The dispute between Wolff and Blumenbach was about whether "the determination of the direction" of development is to be explained by the assumed force or by the circumstances under which the force acts.[29] Blumenbach's formative drive not only drives development, it also determines its direction.

2) Blumenbach established six "laws" about the mode of action of the formative drive, which partly deal with deviations from the "determined direction." From the explanation of the exceptional cases we can draw some conclusions about the regular mode of action. Let us look at the fourth law:

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own, without which no leaf can come into being, as a whole system of changes, which all have their ground there in the first change, and which therefore necessarily, once this series of changes has begun, all follow after one another; and this system of changes then, I say, is completed by bringing forth the fruit, so that the fruit is the last change, which has had its ground in the original disposition or even in the preceding series of changes" (§78, p. 228). On Wolff's embryology, see also S. Roe, "Rationalism and Embryology: Caspar Friedrich Wolff's Theory of Epigenesis," *Journal of the History of Biology 12* (1979), pp. 1–43.

[28] *Bildungstrieb,* 1789 (note 18), p. 89 (emphasis by Blumenbach). [Addition: If this phenomenon is interpreted as the transformation of endoderm into ectoderm, then the observation is incompatible with current knowledge about hydra.]

[29] C. F. Wolff, *Von der eigenthümlichen und wesentlichen Kraft der vegetabilischen sowohl als auch der tierischen Substanz*. in: *Zwo Abhandlungen* [...] (Note 24), pp. 22–23, 65ff. This rarely accessible work is essentially Wolff's criticism of Blumenbach's theory of the formative drive and his defense of the essential force. I quote §32: "I must yet add, that a faculty or force driving the fluids in particular directions, such as Mr. Blumenbach, judging from his expressions, seems to stipulate, cannot occur. If this driving occurs within vessels, then its direction depends not on the driving faculty or force itself but rather on the structure of the vessels, which resist motion in all directions but one and in this manner determine the direction. A repulsive force that acts between two bodies can produce nothing more than a removal of the two bodies from one another, or what comes to the same thing, a removal of the more mobile from the less mobile, and this force has had its effect when the mutually repelling bodies have removed themselves in some manner – whatever the direction may be. Thus, in such a force there lies no ground by which the direction of the motion that the force produces could be determined. The direction along which the repelling bodies are removed from one another depends in any case [*allemahl*] on other circumstances: on their relative positions, on their shapes, or on other bodies located nearby which resist their motions in particular directions and leave motions in other directions open thus determining the direction. This occurs, as already mentioned, with the repulsions within the vessels of animals and plants. In these the motion itself is original and simple; namely it depends solely and immediately on the force, but the determination of the direction is mechanical. However, in other cases the directions can also be determined by attractions. In such cases both of them, the motion itself and the determination of its direction, consequently the entire motion as it takes place, are original and simple. Such was the case in the example adduced above with the motion of the nutrient fluids developed out of the yolk of the egg, which were repelled and set in motion by the yolk itself, but received their determinate direction toward the seat of the embryo by means of its attraction." The determination of the direction of the development, even the whole question of the teleology of the organism reduces to the question of the determination of the direction of the flow of fluids.

> IV. Among the various deviations of the *formative drive* from its definite direction belongs especially the one when, in the formation of *one* kind/species [*Art*] of organic body, it assumes the direction intended for *another* kind of the same.[30]

From this it can be seen that there is only one formative drive, but that it can take different directions and that each *species* has its own direction of the formative drive. And Blumenbach talks more often about the "actually determined direction" or the "specific direction" of the formative drive (he nowhere talks about "formative drives" in the plural).

Also, the greater or lesser variability of the different genera depends on the "constancy" of the formative drive, so that it is sometimes difficult to designate certain genera "by sharply defined specific characters, since the formative drive seems to be less constant with them, but to vary easily in all sorts of individual deviations.[31]

3) In a rather popular scientific work, the *Beyträge zur Naturgeschichte* (Göttingen 1806), one finds Blumenbach's most informative remarks about the formative drive. An organism – he says there – consists for the most part of "cellular tissue" (later he calls it "mucous tissue"). This tissue is "the first organic matter that nature forms from the inorganic fluids," as well as "the first and most important main workshop of the formative drive."[32] In this tissue, therefore, the formative drive first stirs and takes its certain direction. In the *Institutions of Physiology*, he traces the cellular tissue – at least as far as growth and regeneration are concerned – back to the coagulability of an element of the blood: "Thus it itself has its origin, as seems probable to me, from the coagulating lymph of the blood."[33] As for generation and primordial origins of life, the origin of tissue and the occasion for the excitation of the formative drive is the "ripeness" (*Reife*) of other inorganic fluids, such as the already mentioned "raw unformed generative matter." The cellular/mucous tissue is different according to the type of organism; however, Blumenbach speaks at length about only one of the differences: the "suppleness" (*Geschmeidigkeit*), which determines not so much the direction of the formative drive as its constancy.

If we remember that Wolff's essential force should be a prerequisite for the formative drive, we can reconstruct the following picture: Inorganic fluids moving according to their chemical affinities (essential force) produce (by solidification) a particular kind of cellular or mucous tissue. Depending on the mechanical-chemical composition of this tissue, the formative drive stirring in it takes a certain direction. As many kinds of mucous tissue as can be produced by the inorganic matter, so many directions of the formative drive are there, and so many species of organisms are possible in reality. If all organic beings should be destroyed by a catastrophe and the empirically given state of matter should also be changed by this process (which, according to Blumenbach, has already happened at least once), a new animated world would arise. "The only difference is that the formative drive, due to the *material's being differently modified* by such a total revolution, must also take a more or less deviating direction from the previous one in the generation of the new species."[34]

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[30] *Bildungstrieb*, 1789 (note 18), p. 100 (emphasis by Blumenbach).

[31] J. F. Blumenbach: *Abbildungen Naturhistorischer Gegenstände*, Göttingen: Dietrich, 1810 (2nd ed.), no. 66.

[32] *Beyträge* (note 17), 1st ed., pp. 51, 53; 2nd ed., pp. 43, 45; "mucous tissue" (*Schleimgewebe*) instead of "cellular tissue" (*Zellengewebe*) is merely a terminological improvement within Wolff's physiology; see Roe (note 27), pp. 6–7. Blumenbach himself merely refers to a work by Wolff: C. F. Wolff, "De Tela, quam dicunt, cellulosa. Observationes," *Nova Acta Academiae Scientiarum Imperialis Petropolitanae 90* (1788) 259–275.

[33] *Institutiones physiologicae*, Göttingen: Dietrich, 1787, §32

[34] *Beyträge* (note 17), 2nd ed. p. 19–20 (emphasis by Blumenbach).

By the composition of the generative matter the direction of the formative drive and consequently the species membership of the organism is determined. The drive, however, then becomes independently active *throughout life*. "By the certain purposeful effectiveness of the formative drive in the organizable materials receptive to it, the likewise determinate form and the *habitus* of all individual species of organized bodies is now received."[35] The species produced by this therefore depend in the last instance on the properties of matter as it is empirically given on earth.

Here the connection of embryology and classification becomes clear. Individuals are assigned to species according to habitus, i.e., according to the common direction of the formative drive. Species are collected to genera, genera to orders etc. because of the similarity of the habitus (effect) and the direction of the formative drive (cause) to be deduced from this. The task of natural history, then, is to determine from the observation of pragmatically chosen characteristics the habitus of the various species and to infer the species-specific direction of the formative drive, which is the cause of the habitus. Christoph Girtanner, a student of Blumenbach, programmatically states:

> „Natural history, in the philosophical [Kantian] sense, divides the organized bodies into lineages, according to their relations in respect to generation. It is based on the common law of reproduction. Unity of the genus is *unity of the generative power*. In this way, a system of nature arises for the mind, a division of the organized bodies under laws, and especially under the laws of the formative drive."[36]

For Blumenbach, as for Buffon, the species are empirical expressions of the actually possible organizational forms of matter. They reproduce themselves (and arise spontaneously if necessary) on the basis of unchangeable laws of nature. After the last world catastrophe, Blumenbach says, "the Creator probably on the whole let the same natural forces work to the bring forth the new organic kingdoms that had also fulfilled this purpose in the previous world."[37] One can even claim that every individual is spontaneously generated, since it arises from raw, unformed generative matter, although the composition of this matter is rarely the product of the direct action of the laws of nature, but is usually mediated by the physiology of the parents. What is realized in the development of the individual is an individual elaboration of the possibilities given by the species. What is possible for any species is pre-given or "preformed" by the nature of matter. – *In Blumenbach, the epigenesis of the individual implies the preformation of the species*.

4 Queries

In conclusion, I would like to briefly address two questions raised by the philosopher Immanuel Kant in his reflections on the development of biology in this period: first, the question of the "preformation of the species" and second, the relationship of Newtonianism to biology and vitalism – formulated in Kant as the question of the "Newton of the grass blade" – which has been alluded to several times above.

1) Kant remarks in the *Critique of Judgment*, that "the system of epigenesis" can also be called "the system of *generic preformation*, since the productive capacity of the progenitor is still

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[35] *Handbuch*, 5th ed. (Note 2), §10 (emphasis by Blumenbach). Blumenbach writes "aller einzelnen Gattungen (*Species*)."

[36] C. Girtanner, *Über das Kantische Prinzip für die Naturgeschichte*, Göttingen 1796, pp. 4–5 (emphasis by Girtanner).

[37] *Beyträge* (note 17), 2nd ed. p. 19.

preformed in accordance with the internally purposive predispositions that were imparted to its stock, and thus the *specific form* was preformed *virtualiter*." [38]

I would like to refrain here from some elements of the theory of the formative drive that Kant (probably consciously) ignores (e.g., spontaneous generation). I will mention only two points: 1. Kant brings the basic theoretical structure of the various epigenesis theories to a point: they start from the preformation of the species/genus. 2. he continues: Even if one did not know the empirical evidence of the epigeneticist, "*reason* would still already be *favorably disposed* to this explanation because …"[39] The particular reason Kant gives is at first not as interesting as what is to be justified by it: the *bias of reason* in favor of the preformation of the species. Reason is said to be biased in favor of a typological concept of the species, a concept that understands the individual from the outset as a representative of the genus, as a representative of a type that is objectively given as a possible form of organization of matter. Why else was this concept of species taken as a basis, or why was it able to persist until the middle of the next century?

One could claim, of course, that this species concept had to be adopted because of difficulties of explanation in embryology, that the ontogenesis of the individual could be understood as lawful only by means of this concept – one sees that it could hold on longest among the *embryologists* in Germany (e.g., von Baer); it was loosened up only by the *natural historians* in England (e.g., Darwin, Wallace). However, one could point out the other way around that the embryologists came to prominence in *Germany* and the natural historians in *England*.

If one takes Kant's reference to the bias of reason seriously, it seems more plausible that the various epigenesis theories (Buffon, Wolff, Blumenbach) were the way in which ontogeny *had* to be explained*, because* the preformation of the genus was assumed anyway. Biology, after all, was not the only *scientific* discipline that used the concept of species it also played a role in the bourgeois social theories of the seventeenth and eighteenth centuries that claimed to be scientific. As individualistic as these theories were, they attributed certain properties to each individual as *equally* a member of the human species. Such *theories* – developed in confrontation with feudalism and feudal social theory in order to scientifically justify bourgeois relations – presuppose the equal validity of species properties as normatively-evident. It would be worth considering whether the bias of Kant's reason might not be due to a conscious and reflected advocacy of civil society supported, among other things, by the preformation of the species.

2) On the question of the relation between vitalism and Newtonianism in biology, the different editions of *Bildungstrieb* are revealing: the later (and more "vitalistic") the writing, the more Newton quotations.

Ever since Albrecht von Haller compared irritability *(vis insita*) with Newton's gravitational force, it was common to justify new (essential, original, innate) forces and properties with a reference to Newton. Blumenbach, too, introduces his Bildungstrieb as a "in-born" (*ein-*

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[38] Immanuel Kant, *Werke in zehn Bänden*, Darmstadt 1975, vol. 8, p. 543, §81. *Critique of the Power of Judgment* (transl. Paul Guyer /Eric Matthews) New York: Cambridge University Press, 2000, 291

[39] *Op. cit.* 544–545 (emphasis P. M.). The justification reads,: "because it considers nature, at least as far as propagation is concerned, as itself producing rather than merely developing those things that can initially be represented as possible only in accordance with the causality of ends, and thus, with the least possible appeal to the supernatural, leaves everything that follows from the first beginning to nature (without, however, determining anything about this first beginning, on which physics always founders, no matter what chain of causes it tries)" *Critique of the Power of Judgment* (note 38) §81 p. 292.

gebohrne) force (German for *vis insita*) – but without quoting Newton.[40] He quotes Newton only in later writings, where, however, he no longer calls the Bildungstrieb "in-born." In fact: The *only clear difference in content* in the central formulation of the theory of the formative drive between the "more mature" and the "immature" phase is the replacement of an in-born drive with a universal drive.

Newton, however, unlike the Newtonians, did not refer to gravity as an innate force (such as inertia) or as an essential property of matter (such as extension), but always as a universal property of bodies.[41] For Newton, an "essential" property meant a property of a body that belongs to a body, even independent of the system in which the body is located. Such essential properties would belong to a body even if it were the only body in empty space. In contrast, *mutual* attraction always presupposes a system of at least two bodies; it is universal, but not essential. In this respect, Newton's program of tracing back the phenomena of the world system to the *essential* properties of the particles failed; he had to assume a "universal" force *in addition*. (He did not give up the program of explaining the world system by system-independent properties of particles).

Similar to Newton, the vitalists did not give up their basic mechanistic, materialistic position when they could not explain, for example, how life should arise from the mechanical properties of the parts or from organization. They, like Newton, conceived and *superadded* a new force actually illegitimate according to their own ideas (but required by experience). Blumenbach only takes it a bit more precisely than other contemporaries, conceiving the formative drive as a system property – that is, as a universal force, rather than as an essential or innate force of each particle. Just as Newton traced the world system to essential properties of particles *plus gravity*, the vitalists (at least the early ones) trace life to mechanics *plus vital force*.[*] In view of this also methodological parallelism, it would be worth considering whether vitalism is not be the necessary consequence of a consistent Newtonianism in biology. At least this seems to be true for the materialistic vitalism of the late eighteenth century.

[40] *Bildungstrieb*, 1781 (note 18), p. 12: "That in all living creatures, from man to the maggot and from the cedar down to the mold, there lies a special, inborn, lifelong active, effective drive to take on their determinate shape at the beginning, then to preserve it, and if it has been destroyed, to restore it where possible."

[41] For the interpretation of Newton see Gideon Freudenthal, *Atom and Individual in the Age of Newton*, New York: Springer, 1986.

[*] Remark added 2021: Newton's distinction between essential and universal qualities did not survive the early eighteenth century. Qualities that can only appear within a system or within a particular kind of system (gravity, magnetism, life force) could be taken to be intrinsic to every particle but *latent* and thus only displaying effects in a particular context.