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# Abscheulich! (Atrocious!)

Haeckel's distortions did not help Darwin.

By Stephen Jay Gould

Revolutions cannot be kind to prominent and unreconstructed survivors of a superseded age. But the insight and dignity of vanquished warriors, after enough time has elapsed to quell the immediate passions of revolt, often inspire a reversal of fortune in the judgment of posterity. (Even the most unabashed Northerner seems to prefer Robert E. Lee to George McClellan these days.)

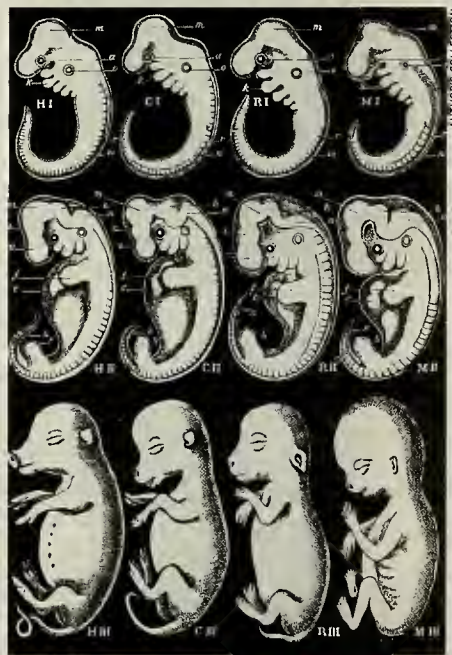
This essay details a poignant little drama in the lives of three great central European scientists caught in the intellectual storm of Darwin's *Origin of Species*, published in 1859. This tale, dormant for a century, has just achieved a vigorous second life, based largely on historical misapprehension and creationist misuse. Ironically, once we disentangle the fallacies and supply a proper context for understanding, our admiration must flow to Darwin's two most prominent opponents from a dispersed and defeated conceptual world: the Estonian (but ethnic German) embryologist and general naturalist Karl Ernst von Baer (1792–1876), who spent the last forty years of his life teaching in Russia; and the Swiss zoologist, geologist, and paleontologist Louis Agassiz (1807–1873), who decamped to America in 1846 and founded Harvard's Museum of Comparative Zoology, where I now reside as curator of the collection of fossil invertebrates that he began. By contrast, our justified criticism must fall upon the third man in the topsy-turvy drama, the would-be hero of a new

world order: German naturalist Ernst Haeckel (1834–1919), the primary enthusiast and popularizer of Darwin's great innovation. Haeckel's forceful, eminently comprehensible, if not always accurate, books appeared in all major languages and surely exerted more influence than the works of any other scientist, including Darwin and Huxley (by Huxley's own frank admission), in convincing people throughout the world about the validity of evolution.

Cynic that I am, I nonetheless confess to hero worship for the raw intellectual breadth and power of three great men: Darwin, who constructed my world; Antoine-Laurent Lavoisier, because the clarity of his mind leaves me awestruck every time I read his work; and Karl Ernst von Baer, who lived too long and became too isolated to win the proper plaudits of posterity. T. H. Huxley, who ranks fourth on my list, regarded von Baer as Europe's greatest pre-Darwinian naturalist.

As the leading embryologist of the early nineteenth century, von Baer discovered the mammalian egg cell in 1827 and, in 1828, published the greatest monograph in the history of the field: *Über Entwicklungsgeschichte der Thiere* (On the Developmental History of Animals). He then suffered a mental breakdown and never returned to the field of embryology. Instead he moved to Saint Petersburg in 1834 (a common pattern for Central European scientists, because Russia, lacking a system of modern education, imported many of its leading professors in scientific subjects). There he enjoyed a long

and splendid second career as an Arctic explorer, a founder of Russian anthropology, and a geomorphologist credited with discovering an important law relating the erosion of riverbanks to the Earth's rotation.



In Ernst Haeckel's drawing, the early embryos (top row) of a pig, dog, monkey, and human are nearly identical.

Von Baer's theories of natural history allowed for limited evolution among closely related forms but not for substantial transformation between major groups. Moreover, he held no sympathy for Darwin's mechanistic views of evolutionary causality. Darwin's book shook the aged von Baer from decades of inactivity in his former zoological realm, and this great man—whom Agassiz, in his last (and posthumously published) article of

1874, would call "the aged Nestor of the science of Embryology"—came roaring back with a major critique entitled *Über Darwins Lehre* (On Darwin's Theory).

In another article written in 1866 to criticize a brave new world that often forgot, and more frequently disparaged, the discoveries of previous generations, von Baer made a rueful comment that deserves enshrinement as one of the great aphorisms in the history of science. Invoking Agassiz, his younger friend and boon companion in rejecting the new theory of mechanistic evolution, von Baer wrote:

*Agassiz says that when a new doctrine is presented, it must go through three stages. First, people say that it isn't true, then that it is against religion, and in the third stage, that it has long been known. (Author's translation)*

Ernst Haeckel, with his characteristic mixture of gusto and bluster, fancied himself a Darwinian general embattled in Agassiz's first two stages, unfurling the new evolutionary banner not only for a biological truth but for righteousness of all stripes. In 1874 he wrote:

*On one side spiritual freedom and truth, reason and culture, evolution and progress stand under the bright banner of science; on the other side, under the black flag of hierarchy, stand spiritual slavery and falsehood, irrationality and barbarism, superstition and retrogression. . . . Evolution is the heavy artillery in the struggle for truth.*

Men of large vision often display outsized foibles as well. No character in the early days of Darwinism can match Haeckel for enigmatic contrast of the admirable and the dubious. No one could equal his energy or the extent of his output—mostly of high

quality, including volumes of technical taxonomic description (concentrating on microscopic radiolarians and on jellyfishes and their allies), and not merely theoretical effusions. Yet no major figure took so much consistent liberty in imposing his theoretical beliefs upon nature's observable factuality.

I won't even discuss Haeckel's misuse of Darwinian notions in the service of a strident German nationalism based on claims of cultural, and even biological, superiority—a set of ideas that became enormously popular and did provide later fodder for Nazi propagandists (obviously not Haeckel's direct fault, although one does bear some responsibility for exaggerated, but not distorted, uses of one's arguments [see Daniel Gasman, *The Scientific Origins of National Socialism: Social Darwinism in Ernst Haeckel and the German Monist League*, London: MacDonalld, 1971]). Let's consider only his drawings of organisms, supposedly a far more restricted subject, imbued with far less opportunity for any "play" beyond sober description.

I do dislike the common phrase "artistic license," especially for its parochially smug connotation (when used by scientists) that creative humanists care little for empirical accuracy. (After all, the best artistic "distortions" record great skill and conscious intent, applied for definite and fully appropriate purposes; moreover, when great artists have chosen to depict external nature as seen through our eyes, they have done so with stunning accuracy.) But I don't know how else to describe

the work of Haeckel, who was, by the way, a skilled artist and far more than a Sunday painter.

Haeckel published books at the explicit interface of art and science—and here he stated no claim for pure fidelity to nature. His *Kunstformen der Natur* (Art Forms in Nature), published in 1904 and still the finest work ever produced in this genre, contains 100 plates of organisms crowded into intricate geometric arrangements. One can identify the creatures, but their invariably curved and swirling forms so closely follow the reigning conventions of art nouveau (called Jugendstil in Germany) that one cannot say whether the plates should be labeled as illustrations of actual organisms or as primers for a popular artistic style.

But Haeckel also prepared his own illustrations for his technical monographs and scientific books—and here he did claim fidelity to nature, as standard practice and legitimate convention also required. Yet Haeckel's critics recognized from the start that this master naturalist, this more than competent artist, took systematic license in "improving" his specimens to make them more symmetrical or more beautiful. In particular, the gorgeous plates for his technical monograph on the taxonomy of radiolarians (intricate and delicate skeletons of single-celled planktonic organisms) often "enhanced" the actual appearances (already stunningly complex and remarkably symmetrical) by inventing structures with perfect geometric regularity.

This practice cannot be defended in any sense, but distortions in technical monographs cause minimal damage, because they rarely receive attention from readers without enough professional knowledge to recognize the fabrications. "Improved" illustrations masquerading as accurate drawings spell much more trouble in popular books intended for general audiences lacking the expertise to sep-

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**Haeckel believed that organisms retrace their evolution as embryos, when they "climb their own family tree."**

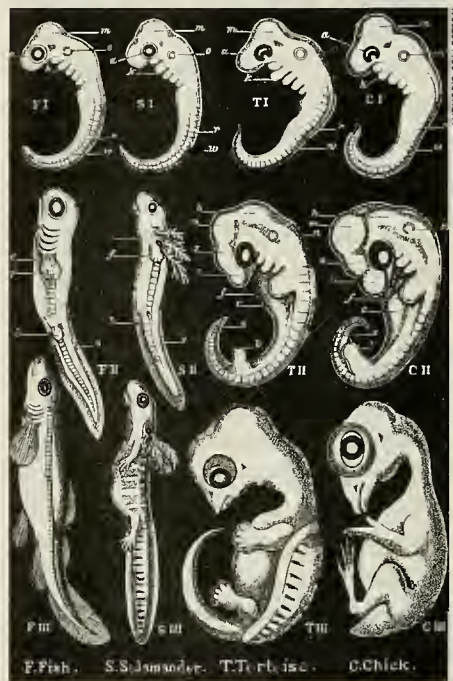


arate a misleading idealization from a genuine signal from nature. And here, in depicting vertebrate embryos in several of his most popular books, Haeckel took a license that subjected him to harsh criticism in his own day and that, in a fierce brouhaha (or rather a tempest in a teapot), has resurfaced in the last two years to haunt him again and even to give some false comfort to creationists.

We must first understand Haeckel's own motivations—not as any justification for his actions but as a guide to a context that has been sadly missing from most recent commentary, thereby leading to the magnification and distortion of this fascinating incident in the history of science. Haeckel remains most famous today as the chief architect and propagandist for a famous argument that science disproved long ago but that popular culture has never fully abandoned, if only because the standard description sounds so wonderfully arcane and mellifluous: “ontogeny recapitulates phylogeny,” otherwise known as the theory of recapitulation or, roughly, the claim that organisms retrace their evolutionary history (or “climb their own family tree,” to cite an old catchphrase) during their embryological development. Thus, the gill slits of the early human embryo supposedly repeat our distant ancestral past as a fish, while the transient embryonic tail, developing just afterward, marks the later reptilian phase of our evolutionary ascent. (My first technical book, *Ontogeny and Phylogeny* [Harvard University Press, 1977], includes a detailed account of the history of recapitulation—an evolutionary notion exceeded only by natural selection itself for impact upon popular culture.)

As primary support for his theory of recapitulation, and to advance the argument that all vertebrates may be traced to a common ancestor, Haeckel frequently published striking drawings showing parallel stages in the develop-

ment of diverse vertebrates, including fishes, chickens, and several species of mammals, from cows to humans (see, for example, page 42). The figure below comes from *Evolution of Man*, an inexpensive popular English translation, published in 1903, of his famous *Anthropogenie*. Note how the latest depicted stages (bottom row) have already developed the distinctive features of adulthood (the tortoise's shell or the chick's beak). But Haeckel drew the



**Fish, salamander, tortoise, and chick also start out looking the same, according to Haeckel's illustration.**

earliest stages (first row), showing tails below and gill slits just under the primordial head, as virtually identical for all embryos, whatever their adult destination. Haeckel could therefore claim that this near identity marked the common ancestry of all vertebrates—for, under the theory of recapitulation, embryos pass through a series of stages representing successive adult forms of their evolutionary history. An identical embryonic stage can only imply a single common ancestor.

To cut to the quick of this drama: Haeckel had exaggerated the similari-

ties by idealizations and omissions. He also, in some cases—in a procedure that can only be called fraudulent—simply copied the same figure over and over again. At certain stages in early development, vertebrate embryos do look more alike, at least in gross anatomical features easily observed with the human eye, than do the adult tortoises, chickens, cows, and humans that will develop from them. But these early embryos also differ far more substantially, one from the other, than Haeckel's figures show. Moreover, Haeckel's drawings never fooled expert embryologists, who recognized his fudgings right from the start.

At this point, a relatively straightforward factual story, blessed with a simple moral message as well, becomes considerably more complex, given the foibles and practices of the oddest primate of all. Haeckel's drawings, despite their noted inaccuracies, entered into the most impenetrable and permanent of all quasi-scientific literatures: standard student textbooks of biology. I do not know how the transfer occurred in this particular case, but the general (and highly troubling) principles can be easily identified. Authors of textbooks cannot be experts in all subdisciplines of their subject. They should be more careful, and they should rely more on primary literature and the testimony of expert colleagues, but shortcuts tempt us all, particularly in the midst of elaborate projects under tight deadlines.

Therefore, textbook authors often follow two suboptimal routes that usually yield adequate results but can also engender serious trouble: they copy from previous textbooks, and they borrow from the most widely available popular sources. No one ever surpassed Haeckel in fame and availability as a Darwinian spokesman and a noted professor at the University of Jena. So textbook authors borrowed his famous drawings of embryonic development, probably quite unaware of their noted



## No one could equal Haeckel's energy or output, yet no major figure took so much liberty with nature's observable factuality.

inaccuracies and outright falsifications—or (to be honest about dirty laundry too often kept hidden) perhaps well enough aware, they then rationalized with the ever tempting and ever dangerous argument “Oh well, it's close enough to reality for student consumption, and it does illustrate a general truth with permissible idealization.” (I am a generous realist on most matters of human foibles. But I confess to raging fundamentalism on this issue. The smallest compromise in dumbing down by inaccuracy destroys integrity and places an author upon a slippery slope of no return.)

Once ensconced in textbooks, misinformation becomes cocooned and effectively permanent, because, as stated above, textbooks copy from previous texts. (I have written two essays on this lamentable practice: one on the amusingly perennial description of the eohippus, or “dawn horse,” as the size of a fox terrier, even though most authors, including yours truly, have no idea of the dimensions or appearance of this breed; and the other on the persistent claim that elongating giraffe necks provide our best illustration of Darwinian natural selection versus Lamarckian use and disuse when, in fact, no meaningful data exist on the evolution of this justly celebrated structure.)

We should therefore not be surprised that Haeckel's drawings entered nineteenth-century textbooks. But we do, I think, have the right to be both astonished and ashamed by the century of mindless recycling that has led to

the persistence of these drawings in a large number, if not a majority, of modern textbooks! Michael Richardson, of the St. George's Hospital Medical School in London, a colleague who deserves nothing but praise for directing attention to this old issue, wrote to me (letter of August 16, 1999):

*If so many historians knew all about the old controversy [over Haeckel's falsified drawings], then why did they not communicate this information to the numerous contemporary authors who use the Haeckel drawings in their books? I know of at least fifty recent biology texts which use the drawings uncritically. I think this is the most important question to come out of the whole story.*

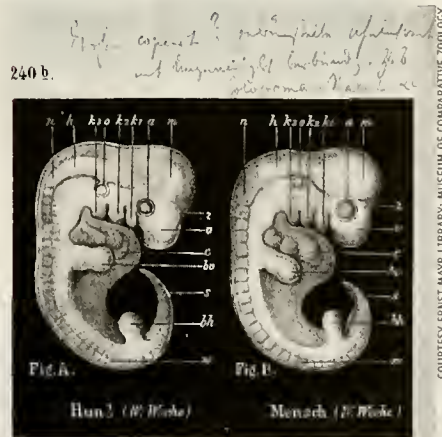
The recent flap over this more-than-twice-told tale—an almost comical manifestation of the famous dictum that those unfamiliar with history (or

cussed the original Haeckel drawings, briefly noted the contemporary recognition of their inaccuracies, properly criticized their persistent appearance in modern textbooks, and then presented evidence (discussed below) of the differences among early vertebrate embryos that Haeckel's tactics had covered up and that later biologists had therefore forgotten. Richardson invoked this historical tale in order to make an important point, also mentioned below, about exciting modern work in the genetics of development.

From this excellent and accurate beginning, the reassertion of Haeckel's old skulduggery soon spiraled into an abyss of careless reporting and self-serving utility. Elizabeth Pennisi's news report in the September 5, 1997, issue of *Science* told the story well, under an accurate headline (“Haeckel's Embryos: Fraud Rediscovered”) and with a textual acknowledgement that Haeckel's work was first “found to be flawed more than a century ago.” But the shorter squib in Britain's *New Scientist* of September 6, 1997, began the downward spiral by implying that Richardson had discovered Haeckel's misdeed for the first time.

As so often happens, this ersatz version, so eminently more newsworthy than the truth, opened the floodgates to a torrent of sensationalist (and non-sensical) assertions: a primary pillar of Darwinism, and of evolution in general, had been revealed as fraudulent after more than a century of continuous and unchallenged centrality in biological theory. If evolution rests upon such flimsy support, perhaps we should question the entire enterprise and give creationists, who have always flubbed their day in court, their day in the classroom.

Michael J. Behe, a Lehigh University biologist who has tried to resuscitate the most ancient and tired canard in the creationist arsenal (Paley's “argument from design,” based on the supposed “irreducible complexity” of in-



**“Where are these copied from?” wrote Louis Agassiz above Haeckel's drawing.**

simply careless in reporting) must be condemned to repeat the past—began with an excellent technical paper by Richardson and six other colleagues in 1997 (*Anatomy and Embryology*, vol. 196), following a 1995 article by Richardson alone (*Developmental Biology*, vol. 172). In these articles, Richardson and his colleagues dis-

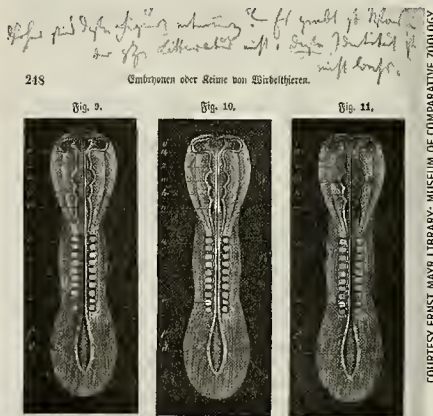
tricate biological structures, a claim well refuted by Darwin himself in his famous discussion of transitional forms in the evolution of complex eyes), reached the nadir in a recent op-ed piece for the *New York Times* (August 13, 1999), commenting on the Kansas Board of Education's decision to make instruction in evolution optional within the state's science curriculum. (In fairness, I liked Behe's general argument in this piece, for he stayed away from irrelevant religious issues and attacked the Kansas decision by saying that we would never get a chance to present his supposed refutations if students didn't study evolution at all.)

As his putatively strongest refutation of Darwinism, Behe cites the ersatz version of Richardson's work on Haeckel's drawings. (Behe discusses only two other arguments for evolution, one that he accepts as true [the evolution of antibiotic resistance by several bacterial strains], the second judged as "unsupported by current evidence" [the "classic" case of industrial melanism in moths], with only this third point—the tale of Haeckel's drawings—declared "downright false." So if this piece represents Behe's best shot, I doubt that creationists will receive much of a boost from their latest academic poster boy.) Behe writes:

*The story of the embryos is an object lesson in seeing what you want to see. Sketches of vertebrate embryos were first made in the late 19th century by Ernst Haeckel, an admirer of Darwin. In the intervening years, apparently nobody verified the accuracy of Haeckel's drawings. . . . If supposedly identical embryos were once touted as strong evidence for evolution, does the recent demonstration of variation in embryos now count as evidence against evolution?*

In this context of media hype and public confusion, we should step back and reassert the two crucial points that

accurately situate Haeckel's drawings as a poignant and fascinating historical tale and a cautionary warning about scientific carelessness (particularly in the canonical and indefensible practices of textbook writing) but not, in any way, as an argument against evolution or as a sign of weakness in Darwinian theory. Moreover, as a testament to greatness of intellect and love of science, whatever the ultimate validity of an underlying worldview, we may look to the work of von Baer and Agassiz, Darwin's most valiant opponents in his own day, for our best illustrations of these two clarifying points.



### Of Haeckel's early pig, dog, and tortoise embryos, Agassiz railed, "Nothing like this exists in the entire literature."

1. *Haeckel's forgeries as old news* (Agassiz's contribution): Tales of scientific fraud excite the imagination for good reason. Getting away with this academic equivalent of murder and then being outed a century after your misdeeds makes even better copy. Richardson reexamined Haeckel's drawings for good reasons and never claimed originality in uncovering the fraud. But press commentary then invented and promulgated this phony version.

Haeckel's expert contemporaries recognized what he had done, and said so in print. For example, a famous 1894 article by Cambridge University

zoologist Adam Sedgwick ("On the Law of Development Commonly Known as von Baer's Law") included the following withering footnote of classical Victorian understatement:

*I do not feel called upon to characterise the accuracy of the drawings of embryos of different classes of Vertebrata given by Haeckel in his popular works. . . . As a sample of their accuracy, I may refer the reader to the varied position of the auditory sac in the drawings of the younger embryos.*

I must confess to a personal reason, emotional as well as intellectual, for long and special interest in this tidbit of history. Some twenty years ago, I found, in the open stacks of our Museum's library at Harvard, Louis Agassiz's personal copy of the first (1868) edition of Haeckel's *Natürliche Schöpfungsgeschichte* (The Natural History of Creation). (After his death, Agassiz's library passed into the Museum's general collection, where indifferent librarianship—before the present generation—led to open access, through nonrecognition, to such priceless treasures.)

I noted, with the thrill that circumstances vouchsafe to an active scholar only a few times in a full career, that Agassiz had penciled copious marginal notes—some forty pages' worth of typed transcription—into this copy. But I couldn't read his scribbles. Agassiz, a typical Swiss polyglot, annotated books in the language of their composition. When he wrote marginalia into a German book published in

Once ensconced in a textbook, misinformation becomes effectively permanent, because textbooks copy from previous texts.



Roman type, he composed the notes in Roman script (which I can read and translate). But when he read a German book printed in old but easily decipherable Fraktur type (as in Haeckel's 1868 edition), he wrote his annotations in the corresponding and now extinct Sütterlin script (which I cannot read at all). The Roman goddess Fortuna then smiled upon me, for my secretary, Agnes Pilot, had been educated in Germany just before the Second World War, and she, *Gott sei Dank*, could still read this archaic script. So she transliterated Agassiz's squiggles into readable German in Roman type, and I could finally sense Agassiz's deep anger and distress.

In 1868 Agassiz, age 61 and physically broken by an arduous expedition to Brazil, felt old, feeble, and bypassed, especially in the light of his continued opposition to evolution (his own graduate students had all "rebelled" and embraced the new Darwinian model). He particularly disliked Haeckel for his crass materialism, his scientifically irrelevant and vicious swipes at religion, and his haughty dismissal of earlier work (which he often shamelessly "borrowed" without attribution). And yet, in reading through Agassiz's extensive marginalia, I sensed something noble about the quality of his opposition, however ill-founded in the light of later knowledge.

To be sure, Agassiz waxes bitter at Haeckel's excesses, as in his final note appended to the closing flourish of Haeckel's book, including the author's gratuitous attack on conventional religion as "the dark beliefs and secrets of a priestly class." Agassiz writes sardonically: "*Gegeben im Jahre I der neuen Weltordnung* (given in year one of the new world order). *E. Haeckel.*" But Agassiz generally sticks to the high road, despite ample provocation, by marshaling the facts of his greatest disciplinary expertise (in geology, paleontology, and zoology) to refute



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Haeckel's frequent exaggerations and rhetorical inconsistencies. Agassiz may have been exhausted and discouraged, but he could still put up one whale of a fight, even if only in private.

Agassiz proceeded in generally measured prose until he came to page 240, where he encountered Haeckel's falsified drawings of vertebrate embryology—a subject of extensive personal research and writing on Agassiz's part (see page 45). He immediately recognized what Haeckel had done, and he exploded in fully justified rage. Above the nearly identical pictures of dog and human embryos, Agassiz wrote: "*Woher copiert? Gekünstelte Ähnlichkeit mit Ungenauigkeit verbunden, z.b. Coloboma, Nabel, etc.*" (Where were these copied from? [They include] artistically crafted similarities mixed with inaccuracies, for example, the eye slit, umbilicus, etc.)

At least these two drawings displayed some minor differences. But when Agassiz came to page 248, he noticed that Haeckel had simply copied the same exact figure three times (see page 46) in supposedly illustrating a still earlier embryonic stage of a dog (left), a chicken (middle) and a tortoise (right). He wrote above this figure: "*Woher sind diese Figuren entnommen? Es gibt sowas in der ganzen Litteratur nicht. Diese Identität ist nicht wahr.*" (Where were these figures taken from? Nothing like this exists in the entire literature. This identity is not true.)

Finally, on the next page, (see page 49) he writes his angriest note next to Haeckel's textual affirmation of this threefold identity. Haeckel stated: "If you take the young embryos of a dog, a chicken, and a tortoise, you cannot discover a single difference among them." And Agassiz sarcastically replied, "*Natürlich—da diese Figuren nicht nach der Natur gezeichnet, sondern eine von der andern copiert ist! Abscheulich.*" (Naturally—because these figures were not drawn from nature,

but rather copied one from the other! Atrocious.)

2. *Haeckel's forgeries as irrelevant to the validity of evolution or Darwinian mechanisms (von Baer's contribution):* From the very beginning of this frenzied discussion two years ago, I have been thoroughly mystified as to what, beyond simple ignorance or self-serving design, could ever have inspired the creators of the sensationalized version to claim that Haeckel's exposure challenges Darwinian theory or even evolution itself. After all, Haeckel used these drawings to support his theory of recapitulation—the claim that embryos repeat successive adult stages of their ancestry. For reasons elaborated at excruciating length in my *Ontogeny and Phylogeny*, Darwinian science conclusively disproved and abandoned this idea by 1910 or so, despite its persistence in popular culture. Obviously, neither evolution nor Darwinian theory needs the support of a doctrine so conclusively disconfirmed from within.

I do not deny, however, that the notion of greater embryonic similarity, followed by increasing differentiation toward the adult stages of related forms, has continued to play an important, although scarcely defining, role in evolutionary theory—but through the later evolutionary version of another

interpretation first proposed by von Baer in his 1828 treatise. In a pre-evolutionary context, von Baer argued that development, as a universal pattern, must proceed by a process of differentiation from the general to the specific. Therefore, the most general features of all vertebrates will arise first in embryology, followed by a successive appearance of ever more specific characters of particular groups.

In other words, you can first tell that an embryo will become a vertebrate rather than an arthropod, then a mammal rather than a fish, then a carnivore rather than a rodent, and finally good old Rover rather than Ms. Tabby. Under von Baer's reading, a human embryo grows gill slits not because we evolved from an adult fish (Haeckel's recapitulatory explanation) but because all vertebrates begin their embryological lives with gills. Fish, as "primitive" vertebrates, depart least from this basic condition in their later development, whereas mammals, as most "advanced," lose their gills, and grow lungs during their maximal embryological excursion from the initial and most generalized vertebrate form.

Von Baer's law, as biologists soon christened this principle of differentiation, received an easy and obvious evolutionary interpretation from Darwin's hand. The intricacies of early development, when so many complex organs differentiate and interconnect in so short a time, allow little leeway for substantial alteration, whereas later stages, with fewer crucial connections to the central machinery of organic function, permit greater latitude for evolutionary change. (In rough analogy, you can always paint your car a different color, but you had better not mess with basic features of the internal combustion engine as your future vehicle rolls down the early stages of the assembly line.)

The evolutionary version of von Baer's law suggests that embryos may give us better clues about ancestry than

**Haeckel:** "With young embryos of a dog, a chick, and a tortoise, you cannot discover a single difference among them."

**Agassiz:** "Naturally—because these figures were not drawn from nature, but rather copied from one another!"



adults—but not because they represent ancestral adults in miniature, as Haeckel and the recapitulationists believed. Rather, embryos indicate ancestry because generalized features of large groups offer better clues than the specialized traits of more restricted lineages can provide. In a standard example, some parasites become so anatomically degenerate as adults that

hinten die gleichen Theile wieder zu erkennen. Wenn Sie die jungen Embryonen des Hundes, des Fisches und der Schildkröte in fig. 9, 10 und 11 vergleichen, werden Sie wohl im Stande sein, einen Unterschied wahrzunehmen. Wenn Sie dagegen die viel später entwickelten Embryonen in fig. G—F mit einander vergleichen, werden Sie schon deutlich die ungleiche Ausbildung erkennen, und namentlich wahr-

**Outraged by Haeckel's distortions, Agassiz ends his marginal comments with "Atrocious."**

they retain no distinctive traits of their larger affiliation. The adult stage of the parasitic barnacle *Sacculina*, for example, becomes little more than an amorphous bag of feeding and reproductive tissue within the body of its crab host. But the larval stages that must seek and penetrate a crab can hardly be distinguished from the early stages of ordinary barnacles. Darwin makes the key point succinctly when he states in *Origin of Species* that "community in embryonic structure reveals community of descent."

Von Baer's law makes good sense, but nothing in Darwinian theory implies or requires its validity, while evolution itself clearly permits embryology to proceed in either direction (or in no linearized manner at all): from embryonic similarity to adult discordance (as in groups that follow von Baer's principle) or from larval discordance to adult likeness (as in several invertebrate groups, notably some closely related sea urchin species, where larvae have adapted to highly different lifestyles of planktonic floating versus development from yolk-filled eggs that remain on the seafloor. Meanwhile, the highly similar adults of

both species continue to live and function like ordinary sea urchins).

The bottom line may now be simply stated: the validity and relative frequency of von Baer's law remains an open, empirical question within evolutionary theory, an issue that can be resolved only by observational evidence from a wide variety of organisms. Moreover, this issue has become quite important in the light of current excitement over recent advances in genetics that have finally allowed us to identify and trace the genes regulating early development. In this crucial and valid context, Richardson wisely chose to reevaluate our complacency about the probable validity of von Baer's law.

Richardson realized that the continuing re-publication of Haeckel's fraudulent figures might be tipping our beliefs in von Baer's favor for indefensible reasons of inherited and unquestioned tradition (based on falsified drawing, to boot) rather than good observational evidence. He therefore called attention to this likely source of unrecognized bias as he marshaled several colleagues to make the basic observations that could resolve a truly open question, falsely regarded by many colleagues as an issue decided long ago, partly on the strength of Haeckel's doctored evidence.

The jury will be out for some time as they debate and actively research this important issue, too long neglected, in the sciences of natural history. But the 1997 paper by Richardson and six colleagues has already poked some important holes in the old and (as we now learn) poorly documented belief in early embryonic similarity among related lineages, followed by increasing disparity toward adulthood. The early embryonic stages of vertebrates are not nearly so similar as Haeckel's phony drawings had led us to believe. For example, at the stage that Haeckel chose for maximal similarity, the number of somites (vertebral segments) of actual embryos ranges from eleven for a

Puerto Rican tree frog to sixty for a blindworm (the common name for an unfamiliar group of limbless amphibians with a basically snakelike adult form). Moreover, although Haeckel drew his embryos as identical in both size and form, actual vertebrate embryos at their stage of maximal anatomical similarity span a tenfold range in body size.

In short, the work of Richardson and colleagues goes by a simple and treasured name in my trade: good science. The flap over Haeckel's doctored drawings should leave us feeling ashamed about the partial basis of a widely shared bias now properly exposed and already subjected to exciting new research. But Haeckel's High Victorian (or should I say Bismarckian) misdeeds provide no fodder to foes of Darwin or of evolution.

In other words, to give von Baer and Agassiz a final due, we need not fear the first and second stages of a scientific revolution, because we will fight like hell (perhaps unwisely and too well but at least with gusto) so long as we regard a new idea as either ridiculous or opposed to "religion" (that is, to conventional belief). But we must beware the dreaded third stage, for when we capitulate and then smugly state that we knew it all along, we easily fall into the greatest danger of all—smug complacency—because we have ceased to question and observe. And no situation in science could possibly be more *abscheulich*—atrocious!

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**Erratum:** The portrait of Marcel Duchamp in the 12/99–1/00 issue of *Natural History* was incorrectly credited. The photographer was Victor Obsatz, to whom we apologize for the error.