

Topics of Chapter 13

1. The hidden bond of affinity in classification—common descent (the natural system).
2. Morphology—role of homology and the archetype
3. Embryology—the recapitulation thesis
4. Rudimentary organs—explained by disuse.

Review of the *Origin of Species*

“The chief arguments used to establish the theory rest on conjecture. Beasts may have varied; variation may have accumulated; they may have become permanent; continents may have arisen or sunk, and seas and winds been so arranged as to dispose of animals just as we find them; now spreading a race widely, now confining it to one Galapagos Island. ... We are asked to believe all these maybe's happening on an enormous scale, in order that we may believe the final Darwinian 'maybe,' as to the origin of species. The general form of his argument is as follows: All these things may have been, therefore my theory is possible, and since my theory is possible, all those hypotheses which it requires are rendered probable. There is little direct evidence that any of these maybe's *actually have been*.”

Fleeming Jenkin, *North British Review* (June 1867).

The Evidence for Evolutionary Transformation: One Long Argument

Positive evidence

1. Artificial Selection (especially uncon. selection) (chap. 1)
2. Patterns of speciation—large genera have large species (chap. 2)
3. The logic of Nat. Sel.—nat. sel. Logical consequence of three facts: heritable variation; superfecundity; struggle for existence. Hence, alteration of species.

The Evidence for Evolutionary Transformation

The “mathematical” demonstration:

1. Existence of variation
2. Inheritance of traits, including variations
3. Superfecundity of organisms
4. Limited resources, thus struggle

Darwin claims these are facts that cannot be denied. But as a result: natural selection and/or evolution

The Evidence for Evolutionary Transformation: One Long Argument

Positive evidence

1. Artificial Selection (especially uncon. selection) (chap. 1)
2. Patterns of speciation—large genera have large species (chap. 2)
3. The logic of Nat. Sel.—nat. sel. Logical consequence of three facts: heritable variation; superfecundity; struggle for existence. Hence, alteration of species.
4. Explanation of social insects, easily and elegantly explained. (chap. 7)
5. Fossils, though scant
6. Biogeographical relationships: organisms on islands close to mainland vs distant from mainland
7. Materials of chap. 13:
 - a. Classification (systematics)
 - b. Morphology (homology)
 - c. Embryology
 - d. Rudimentary characters

Chapter 13:

1. The hidden bond of affinity in classification—common descent (the natural system).
2. Morphology—role of homology and the archetype
3. Embryology—the recapitulation thesis
4. Rudimentary organs—explained by disuse.

$T \rightarrow O_1, T \rightarrow O_2, T \rightarrow O_3, T \rightarrow O_4$

But, O_1, O_2, O_3, O_4

Therefore T

Or the probability of $O_{1...n}$, given T vs.

Probability of $O_{1...n}$, given Creation.

E.g., what is probability of animal distribution on islands, given that Creationism is true? Or what is the probability of homologies, if Creationism is true.

Darwin's Popperian Arguments

1. The logic of induction:

$T \rightarrow O$,
But O ,
Therefore T

.

2. The logic of falsification:

$T \rightarrow O$,
But $\sim O$,
Therefore $\sim T$.

Examples of Critical Attitude:

1. If one animal acts solely for the good of another, his theory is false.
2. If a trait cannot arise through gradual modification of another trait, then his theory is false.
3. What would falsify Creation theory?
 - a. You might think that Moses could not have loaded Kangaroos on the Ark, that would falsify a literal Creationism.
 - b. Does Albrecht Dürer falsify the Creation Story?

Albrecht Dürer
Adam and Eve, 1507

Are the portraits
morphologically correct?



The Issue of Classification (Systematics)

The Chinese Encyclopedia *Celestial Emporium of Benevolent Knowledge*, in which it is written that animals are divided into:

1. those that belong to the Emperor,
2. embalmed ones,
3. those that are trained,
4. suckling pigs,
5. mermaids,
6. fabulous ones,
7. stray dogs,
8. those included in the present classification,
9. those that tremble as if they were mad,
10. innumerable ones,
11. those drawn with a very fine camelhair brush,
12. others,
13. those that have just broken a flower vase,
14. those that from a long way off look like flies.

From Jorge Luis Borges, “The Analytical Language of John Wilkins.”

REGNUM ANIMALE.

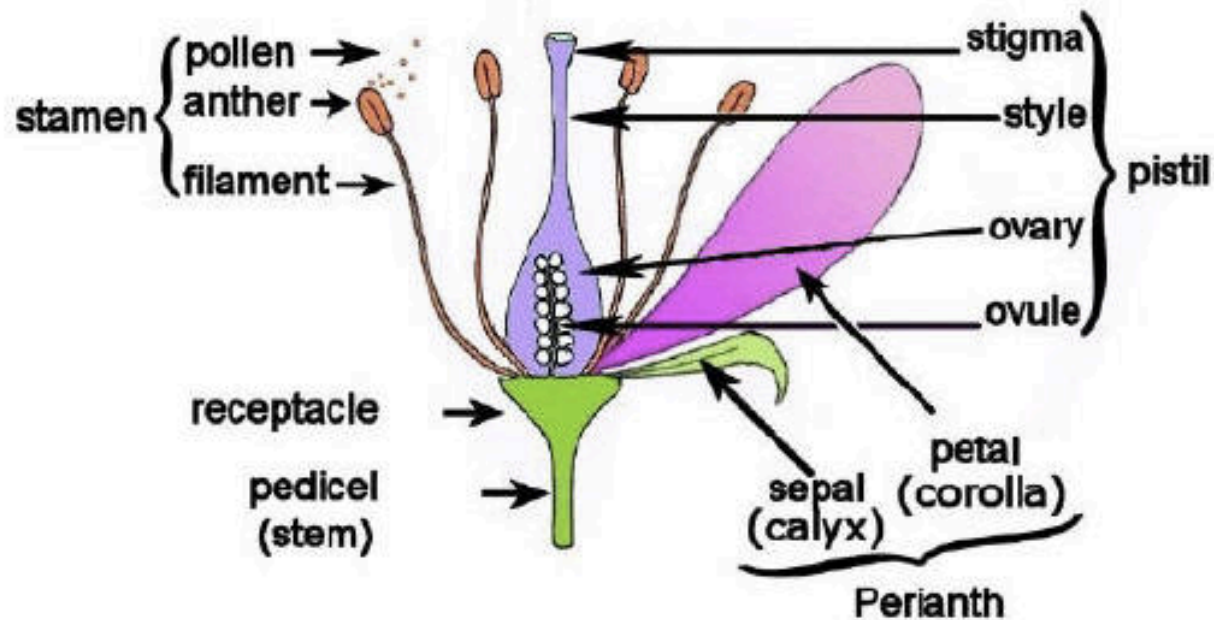
VI. VERMES.

Corporis *Musculi* ab una parte basi cuidam solidæ affixi.

NEPHELIA 18-20	Gordius.	<i>Corpes filiforme, teres, duplex.</i>	Sens apertius. Vires nitens.
	Tania.	<i>Corpes filiforme, plenum, articulosum.</i>	Lenticulus longus.
	Lumbricus.	<i>Corpes teres, annulo prominenti distinctum.</i>	Incantum terre. Lenticulus ann. Albidus.
	Hirudo.	<i>Corpes infimo plenum, fupremo concave. truncato declinatum.</i>	Sanguisuga.
	Limax.	<i>Corpes infimo plenum, fupremo conc. truncato declinatum.</i>	Limax.
TESTACEA. 18-20	Concha.	<i>Tyfa univaria, fupilis, uniloculari.</i>	Helix. Labyridium. Cyprina. Concha varia. Sordidum. Cyprina. Turbo. Cyprina. Strombus? Pulvis. Teredonum. Murex. Purpur. Aporrhais. Nerita. Trochus.
	Nautilus.	<i>Tyfa univaria, fupilis, multiloculari.</i>	Nautilus. Cyprina. Lima.
	Cyprina.	<i>Tyfa univaria, convoluta, siliis lo- gitudinali.</i>	Concha Venetia. Purpurina.
	Halioctis.	<i>Tyfa univaria, parva, leviter concave, perforata, ad angulum fupilis.</i>	Astra maris.
	Purcella.	<i>Tyfa univaria, concave, simplex.</i>	Purcella.
DENTATA. 18-20	Dentalium.	<i>Tyfa univaria, teres, duplex.</i>	Dentalium. Lapillum. Tubus verrucosus.
	Concha.	<i>Tyfa bivalvis.</i>	Mytilus. Pecten. Vulva maris. Pecten. Cyprina. Chama. Pecten. Terebra. Pecten. Cyprina. Pecten. Murex. Pecten.
	Lepas.	<i>Tyfa multivaria, fupilis distincta plenum.</i>	Concha caustica. Vermis nudus. Cyprina nudus.
ZOOEPHIA. 18-20	Tethys.	<i>Corpes forma variabilis, molle, nudum.</i>	Tethys. Cyprina. Pecten maris.
	Echinus.	<i>Corpes fibrosum, testa nudum, sco- lus nudum.</i>	Echinus nudus.
	Asterias.	<i>Corpes radiatus, corio testum, fibrum.</i>	Tethys maris. Tethys oligostoma. Tethys bivalvis. Tethys polydactylus.
	Medusa.	<i>Corpes orbiculatum, gelatinosum, foli- um fibrosum.</i>	Urtica maris. Tethys nudum. Tethys nudum. Tethys nudum.
	Sopia.	<i>Corpes elongatum, interne osatum, ex- terius cito articulo distinctum.</i>	Cyprina. Lapillum.
	Microcosmus.	<i>Corpes variis intersegetis nudum.</i>	Microcosmus nudus.

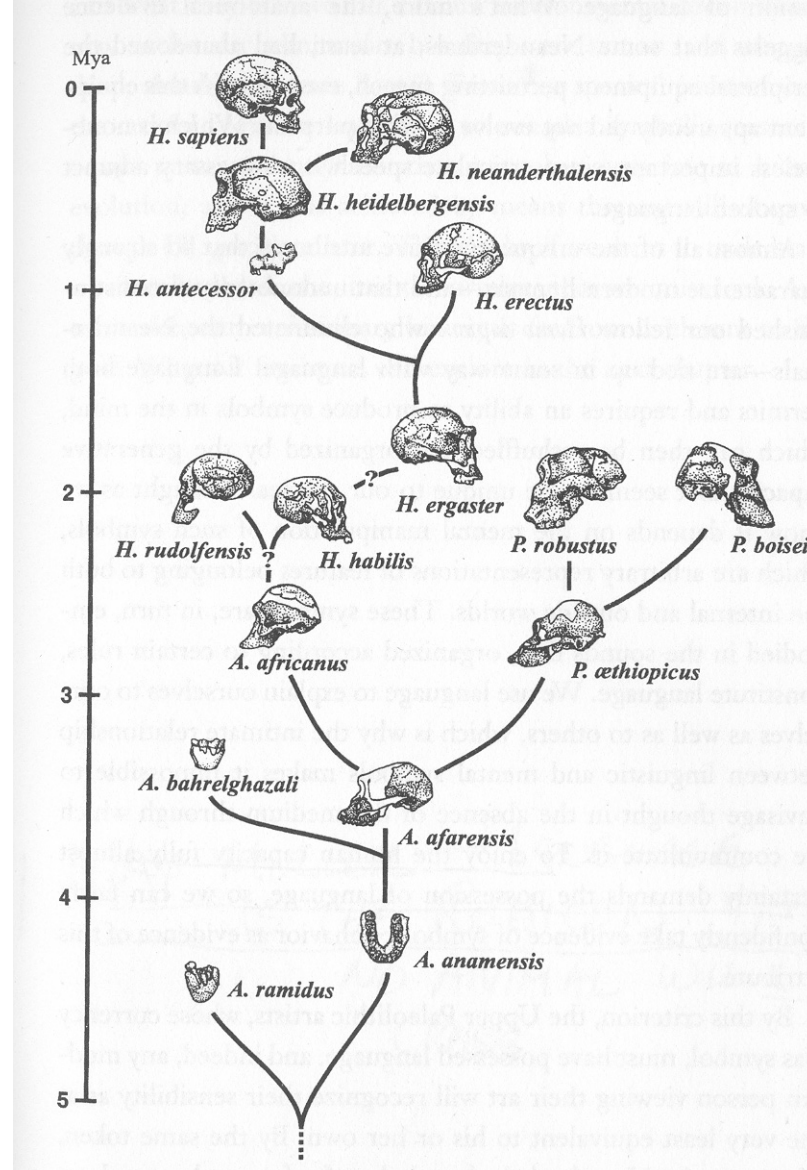
Artificial vs. Natural System of Classification

Parts of a Flower

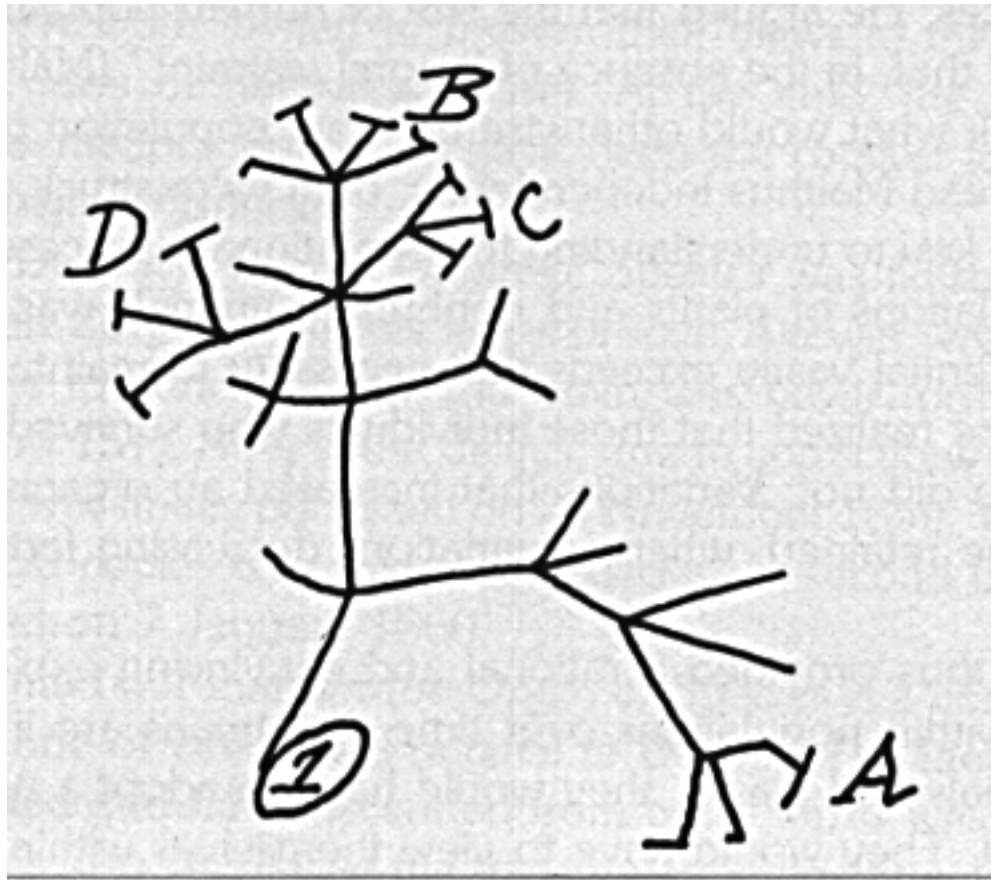


Kingdom: Animalia
Phylum: Chordata
Subphylum: Vertebrata
Class: Mammalia
Order: Primates
Family: Hominidae (includes great apes)
Genus: Homo (homo erectus, etc.)
Species: sapiens

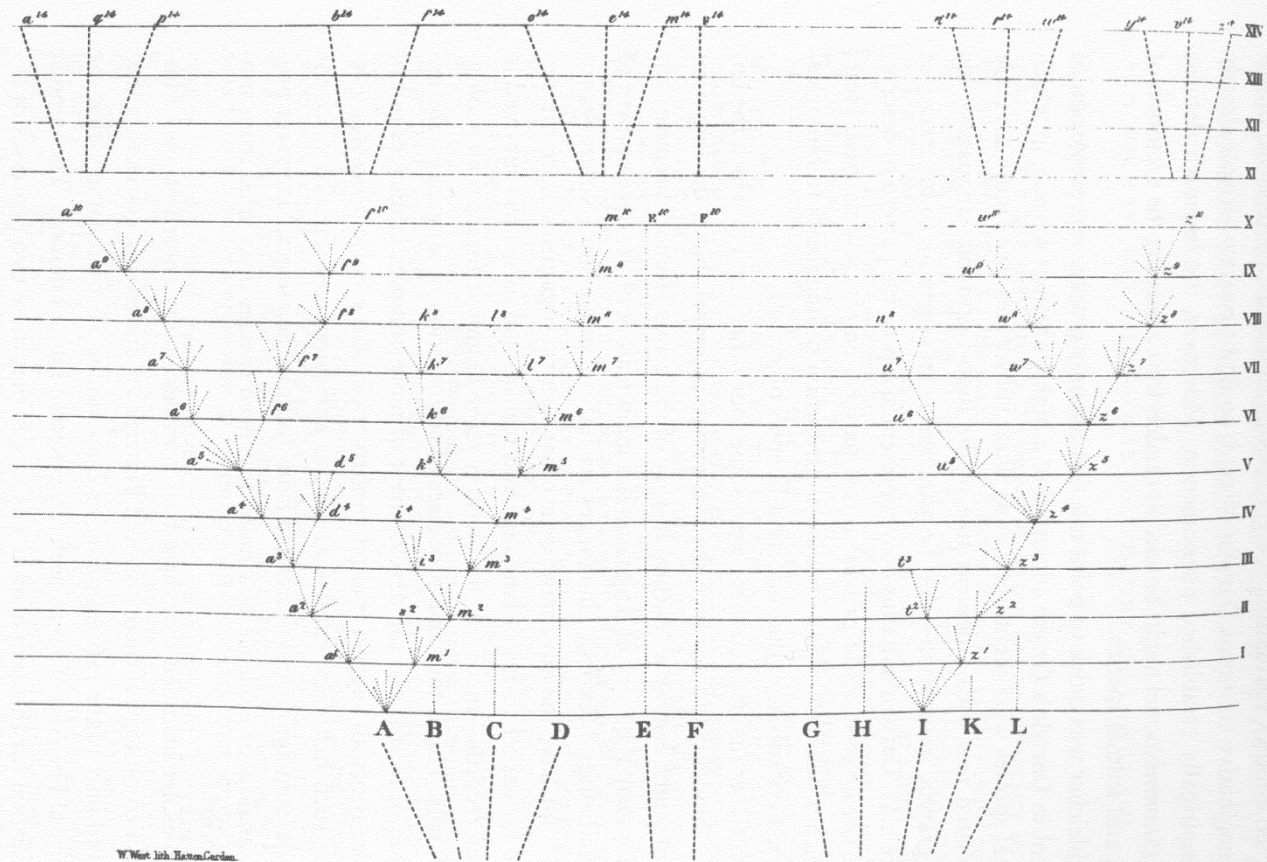
Linnaean Taxonomic Categories: Human Beings

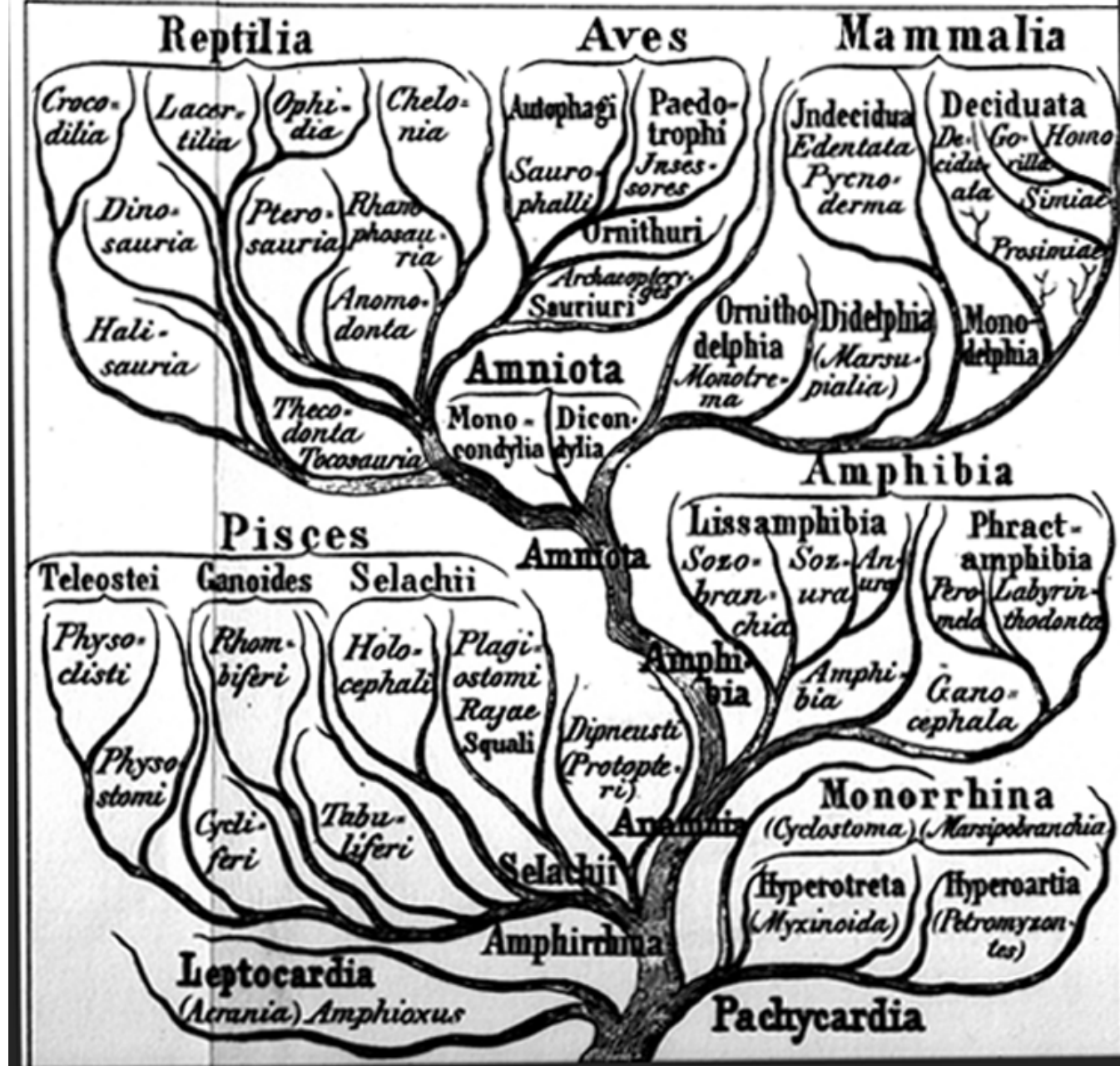


The more proximate human lineage, from Australopithecus to Homo, with side branch to Paranthropus

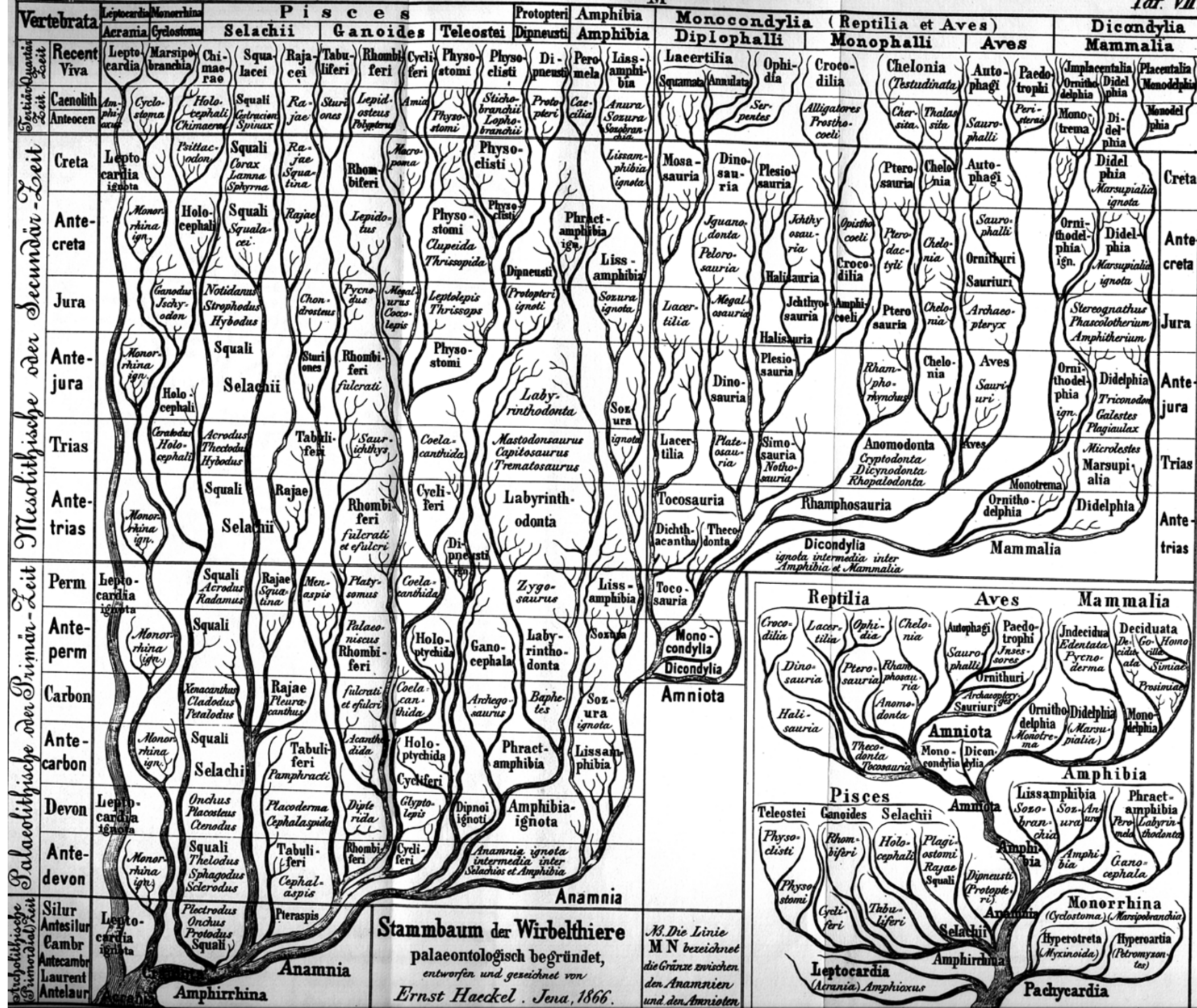


Darwin's sketch from Notebook B, 1837



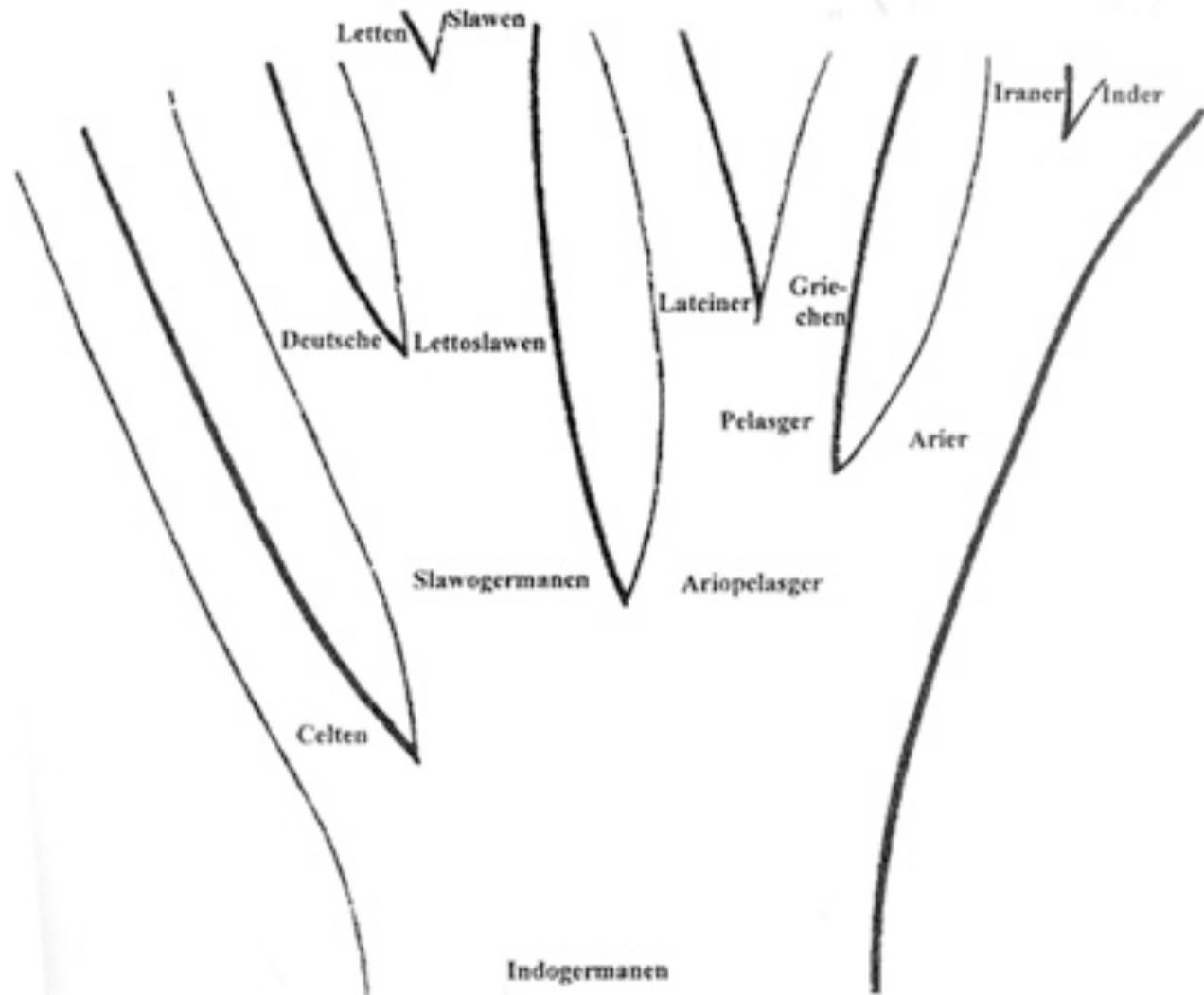


Ernst Haeckel's Tree of Systematic Relationships (*Generelle Morphologie* (1866))

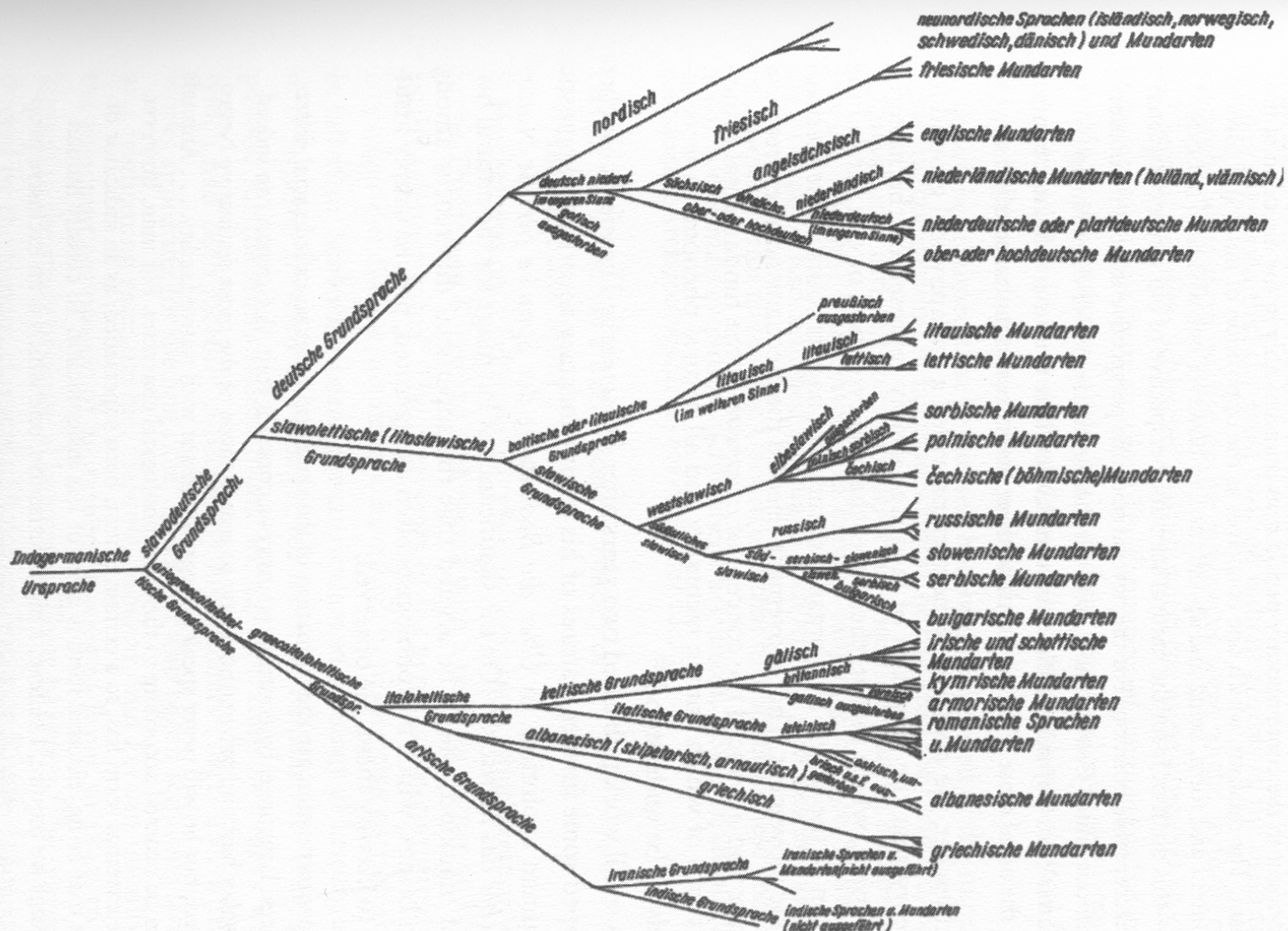


Stammbaum der Wirbelthiere
palaeontologisch begründet,
entworfen und gezeichnet von
Ernst Haeckel . Jena, 1866.

N. Die Linie
MN bezeichnet
die Gränze zwischen
den Anamniern
und den Amnioten

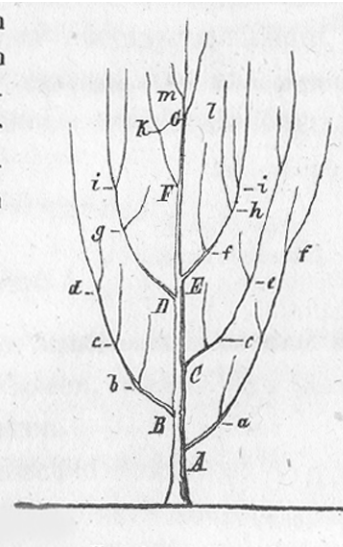


August Schleicher's first language tree diagram. From "Die ersten Spaltungen des indogermanischen Urvolkes," Allgemeine Zeitschrift für Wissenschaft und Literature (August 1853).



Schleicher's tree to Indogerman languages, from his *Darwinsche Theorie und die Sprachwissenschaft* (1863)

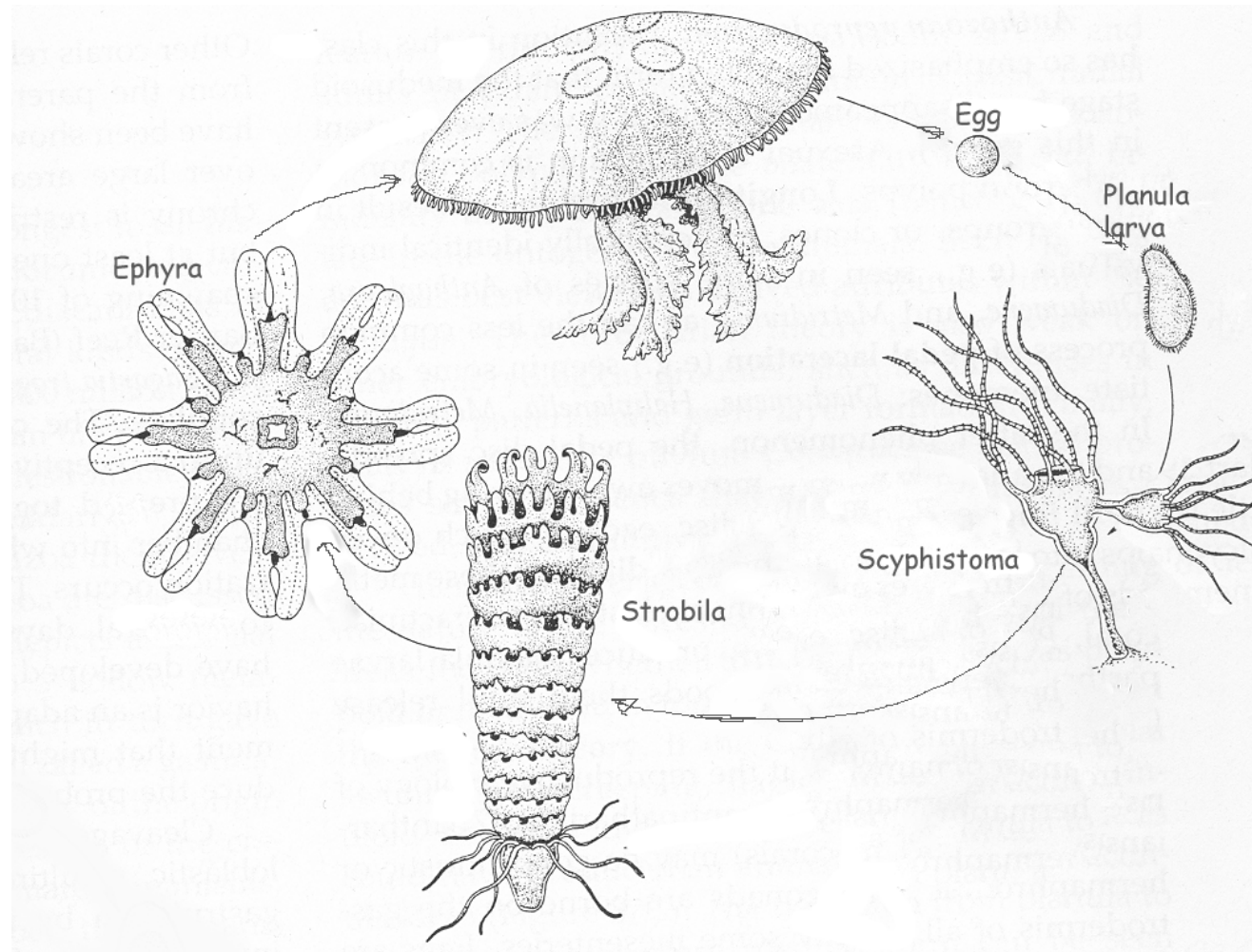
Es ergibt sich aus den vorangehenden Untersuchungen, dass nicht nur die Wirbel-losen Thiere, die Fische, die Reptilien, die warmblüthigen Vögel und Säugthiere und zuletzt der Mensch allmählich erst die einen nach den andern auftreten, — sondern auch in den einzelnen Unterreichen der Strahlenthier, der Weichthiere, der Korbthiere, der Fische die höheren Äste des Sytemes erst nach den tieferen erscheinen, — jedoch in der Weise, dass der höhere Zweig eines tieferen Astes sich oft später als der tiefere Zweig eines höheren Astes entwickelt. Will man dieses Verhalten durch ein Bild darstellen, so wird dasselbe einem solchen Baum-förmigen Bilde des Sytemes entsprechen.



Heinrich Georg Bronn (1800-1862): Untersuchungen ueber die Entwicklungs-Gesetze der organischen Welt, 1858.



Portuguese-man-of-war



Alternating generations in case of jelly fish

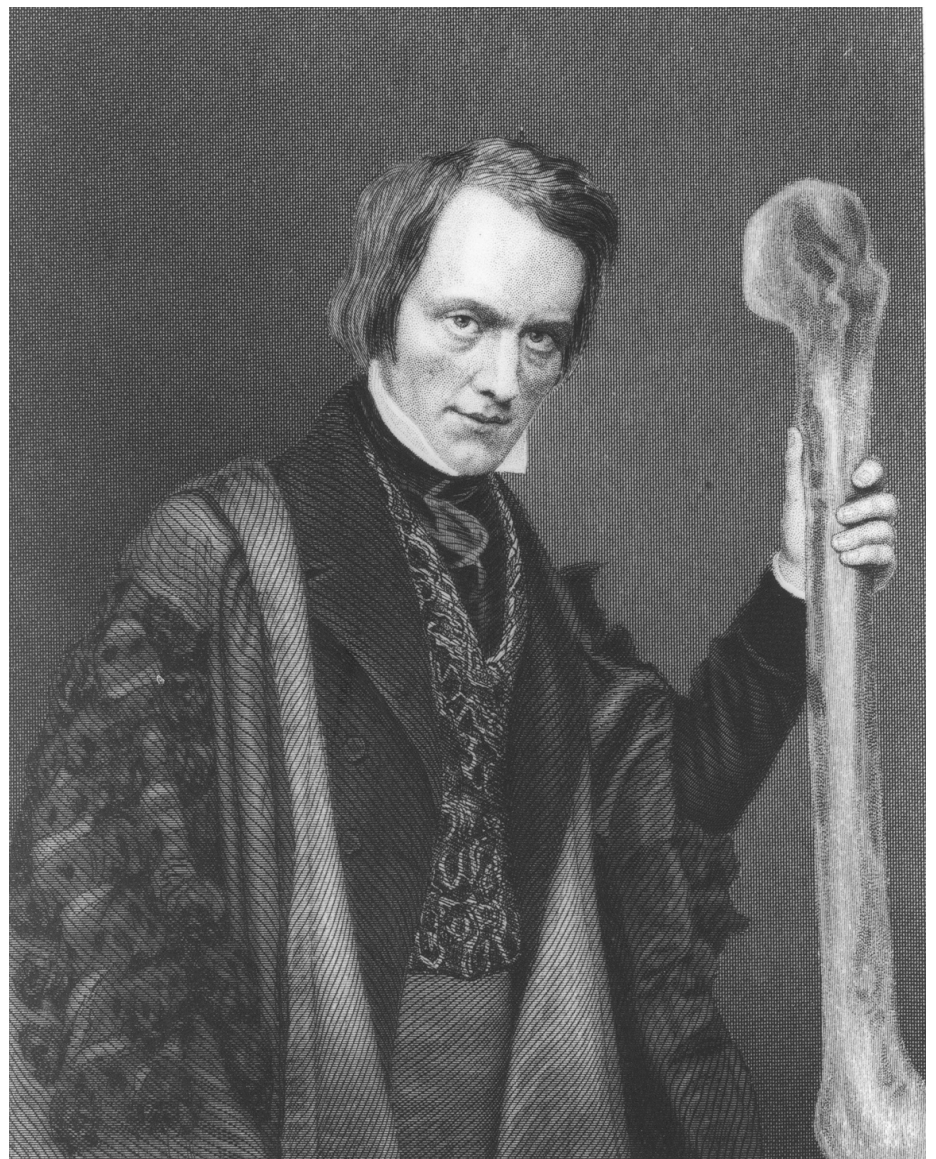
The Principle of Classification

1. Chose traits of little importance, since important traits may differ in related organisms due to selection.
2. Aggregation of traits best means of organization.
 - a. Otherwise you might use an inappropriate trait to construct your descent tree—e.g., two-footed would place birds and humans together.

- 2. Morphology
 - a. Homology
 - b. Archetypes



Carl Gustav Carus (1789-1869)

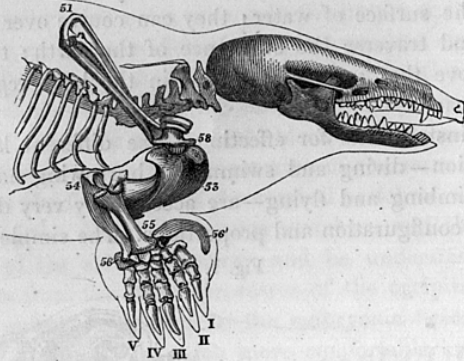


Richard Owen (1804-1892)

tusely pointed paddle or oar; without other apparent joint than that which unites it to the body it has to propel: a joint permitting that degree of rotation with the oblique stroke that makes the movement of the oar most effective.

The instrument for burrowing, such as the Mole presents (fig. 2), is not very different in form and character

Fig. 2.



External form and skeleton of the fore-limb of the Mole (*Talpa Europaea*).

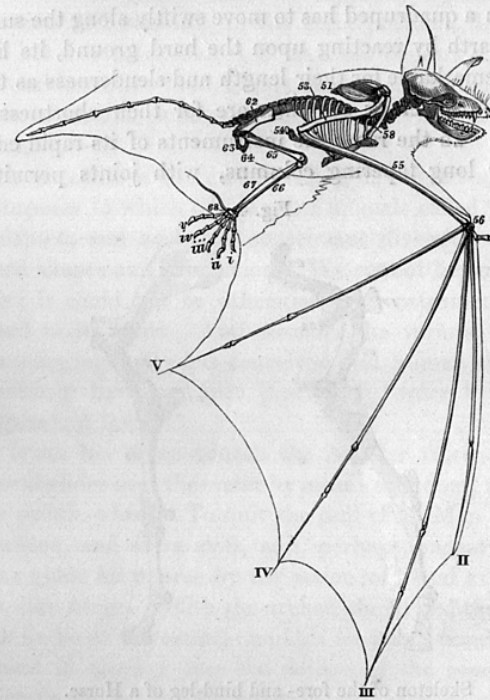
from the fin; but being destined to displace a denser element than water, it is shorter in proportion to its breadth, and much stronger: it resembles the fin in consisting, seemingly, of but one segment or joint, and being moveable as a whole only where it is set on to the trunk. The free border, however, instead of being smooth and thin, is notched, and armed with a row of hard, tooth-like, horny

were so denominated from a loose appreciation of this analogy, and convenience obviously suggests their retention in an arbitrary sense. To attempt to change the application of these names from a supposed more accurate appreciation of the analogical resemblance, argues either a mind more subservient to nomenclature than zealous for the advancement of the science of Nature; or an ignorance of the distinct systems to which the skeletons of the limbs of Articulates and Vertebrates owe their origin.

points, adapted for scraping and throwing back the soil. With such rapidity does the mole effect this purpose*, that it may literally be said to 'swim through the earth.'

The third form of limb or locomotive member here exhibited (fig. 3), offers a striking contrast to the burrowing

Fig. 3.

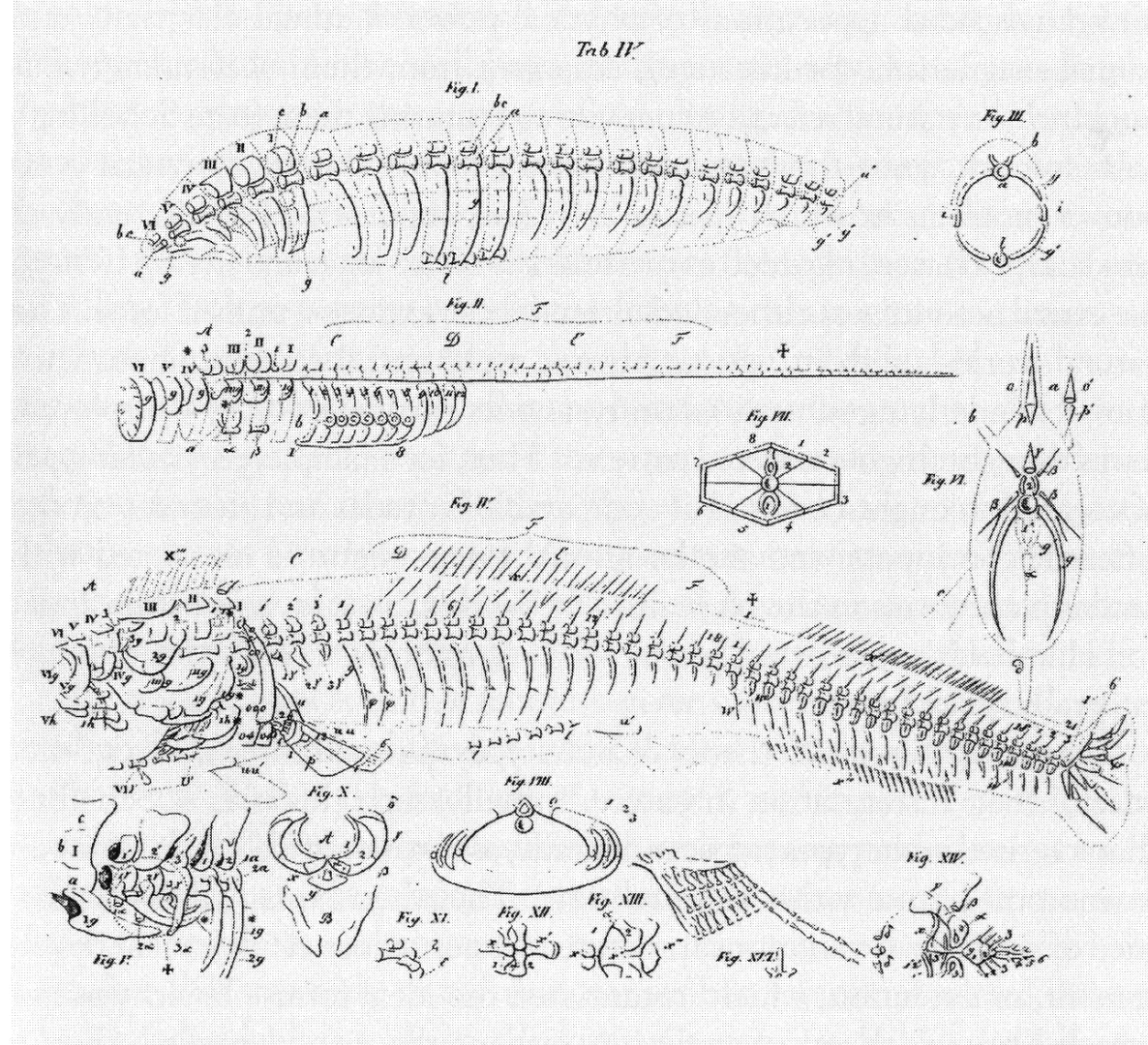


External form and skeleton of the wing of the Bat.

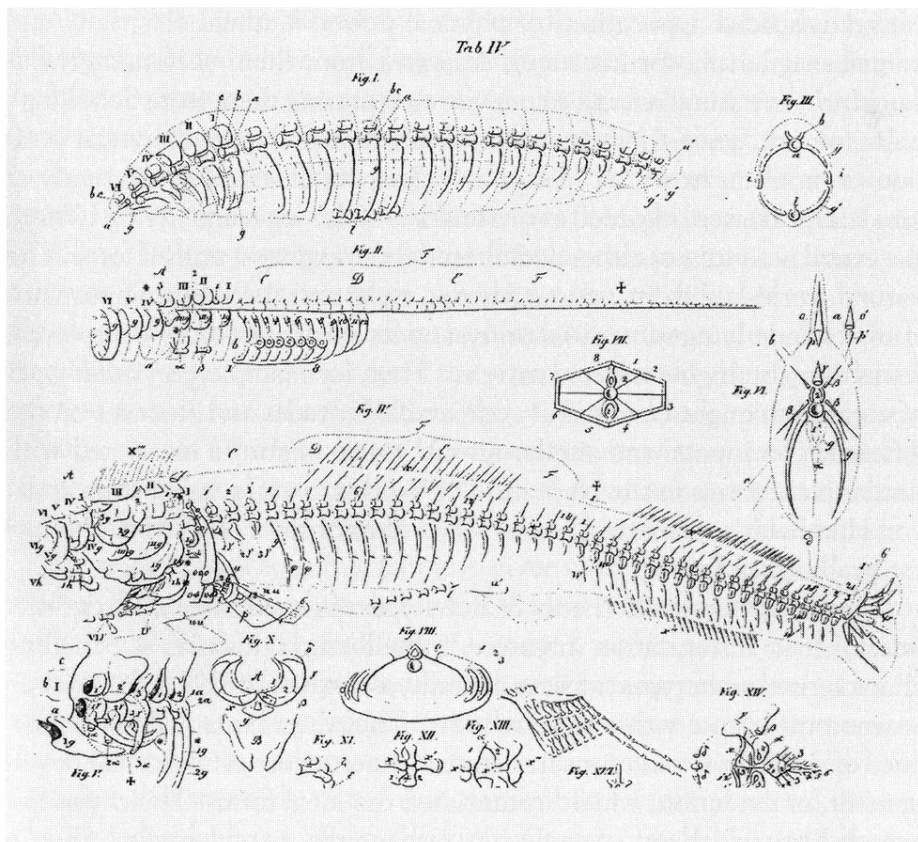
trowel we were last contemplating. It is a thin, vastly expanded sheet of membrane, sustained, like an umbrella, by slender rays, and flapped by means of these to and fro

* Prof. Bell, History of British Quadrupeds, p. 96, 8vo, Van Voorst.

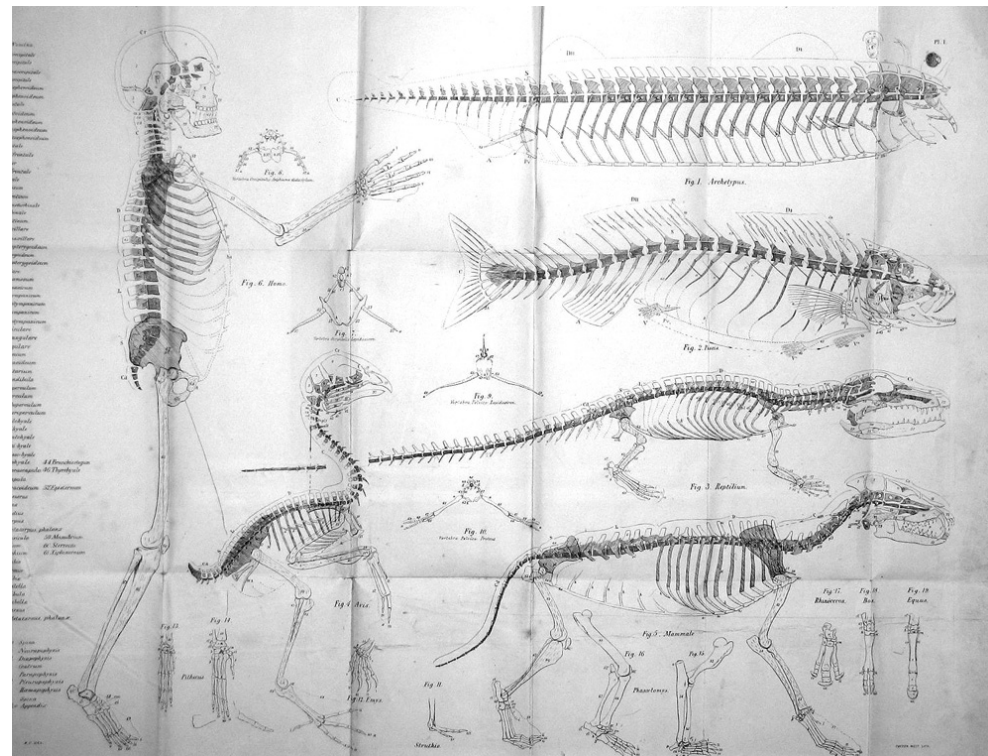
Telic adaptations of limbs, from Richard Owen, *On the Nature of Limbs* (1849).



Carl Gustav Carus's representation of the vertebrate archetype (Fig. 1), and its instantiations. From his *Von der Ur-Theilen des Knochen und Schalengerustes* (1828)



Carus's illustration of the archetype



Richard Owen's illustration of the archetype, from his *On the Nature of Limbs* (1849)

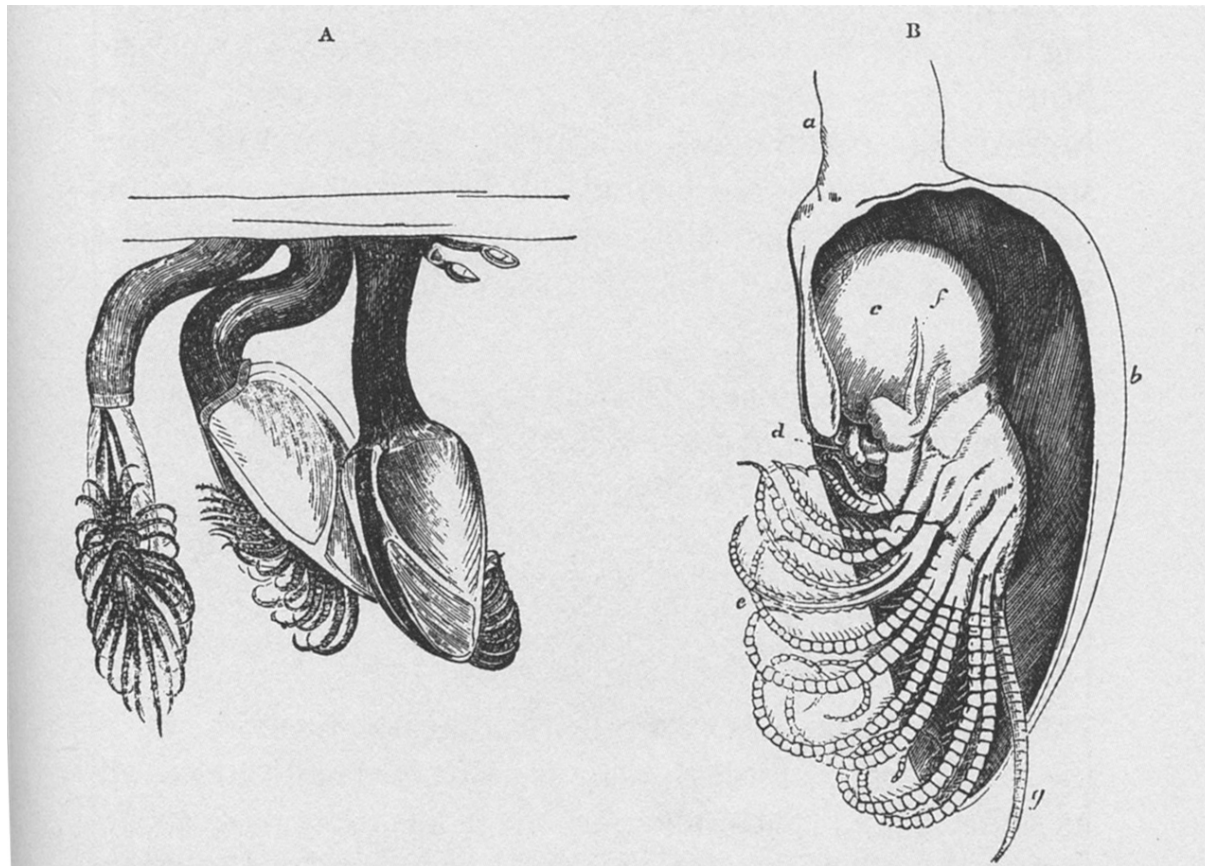
“I look at Owen’s Archetypes as more than idea, as a real representation as far as the most consummate skill & loftiest generalization can represent the parent form of the Vertebrata.”

Darwin’s copy of Owen’s *On the Nature of Limbs*, back flyleaf.

Darwin concludes concerning recapitulation

“Embryology rises greatly in interest, when we thus look at the embryo as a picture, more or less obscured, of the common parent-form of each great class of animals.”

Darwin, *Origin*, p. 450



Barnacles after adhesion and metamorphosis, from Darwin' Barnacles Books

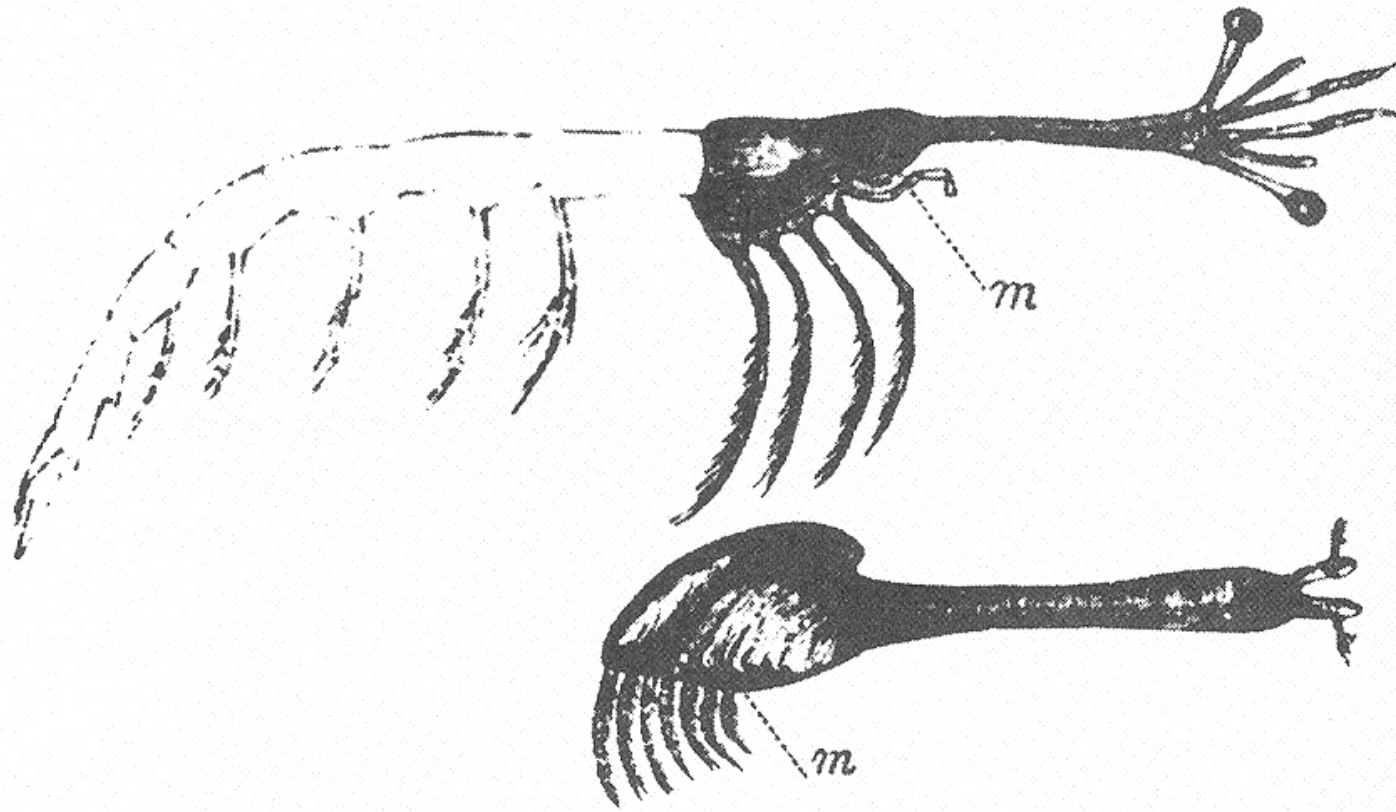
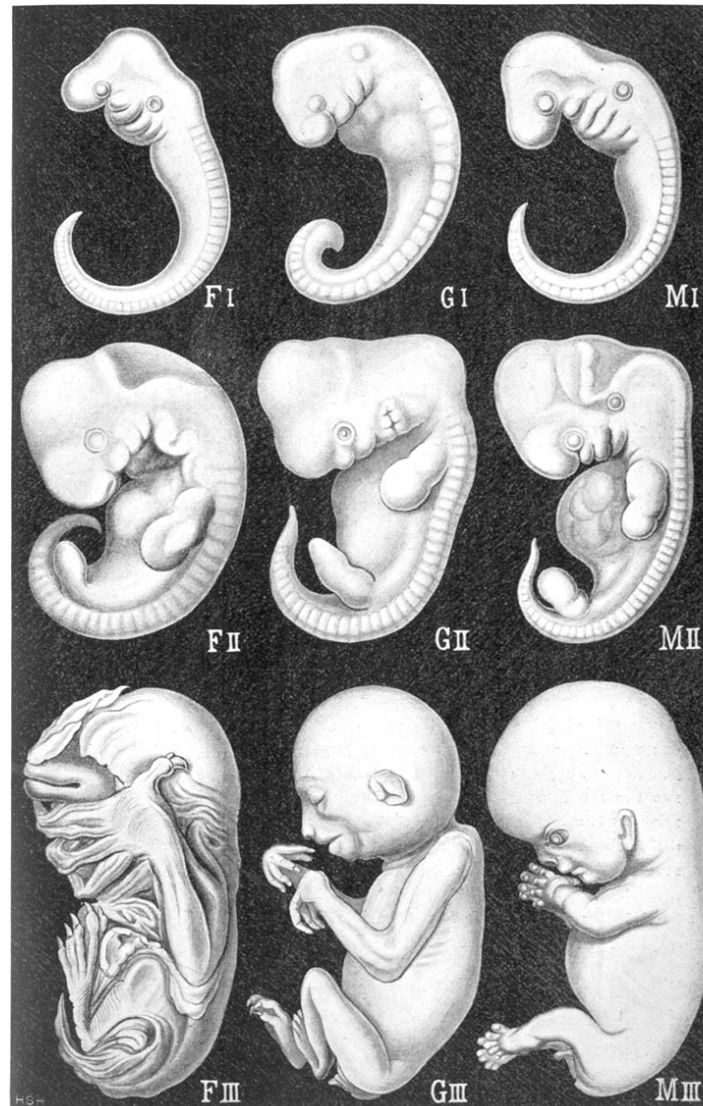


Illustration of the homologies between a Stomapod crustacean (with posterior only sketched) and a Lepas barnacle larva (m indicates a mouth), from Charles Darwin, *A Monograph of the Sub-Class Cirripedia: the Lepadidae* (1851). Naturalist had assumed the barnacle to be a mollusk (like clams and oysters).

Keime (Embryonen) von drei Säugetieren
(auf drei ähnlichen Entwicklungsstufen).



F = Fledermaus (Rhinolophus) G = Gibbon (Hylobates) M = Mensch (Homo)

From Ernst Haeckel's *Der Kampf um den Entwicklungs-Gedanken* (1905).

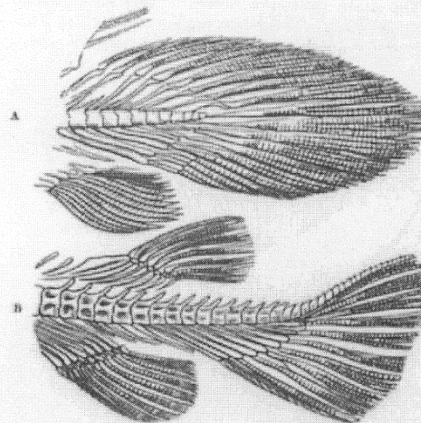
Darwin's Principle of Recapitulation

“As the embryonic state of each species and group of species partially shows us the structure of their less modified ancient progenitors, we can clearly see why ancient and extinct forms of life should resemble the embryos of their descendants—our existing species.”

Darwin, *Origin*, p. 449

great number of species whose remains are known to us, the evidence seems conclusive that all the Fishes of that time, whatever may have been their degree of development in other respects, could have not advanced beyond the embryonic grade of the greater number of existing Fishes, as regards the structure of their spinal column. Moreover, in nearly all the earlier Fishes, as was first pointed-out by Prof. Agassiz, we find a conformation of the tail which differs from that prevailing amongst the existing Fishes, but corresponds with that which presents itself in the embryonic state of the latter. For in most of the Osseous fishes of the present epoch, the bodies of several of the terminal caudal vertebrae coalesce, so that the spinal column appears to end abruptly, whilst their neural and haemal arches and spines are equally developed above and below, so as to form the 'homocercal' tail represented in Fig. 78, A; in almost every Fish anterior to the Liassic period, on the other hand, the tail was formed upon the 'heterocercal' type, the vertebral column being continued onwards into its upper lobe, which is consequently the largest (B).

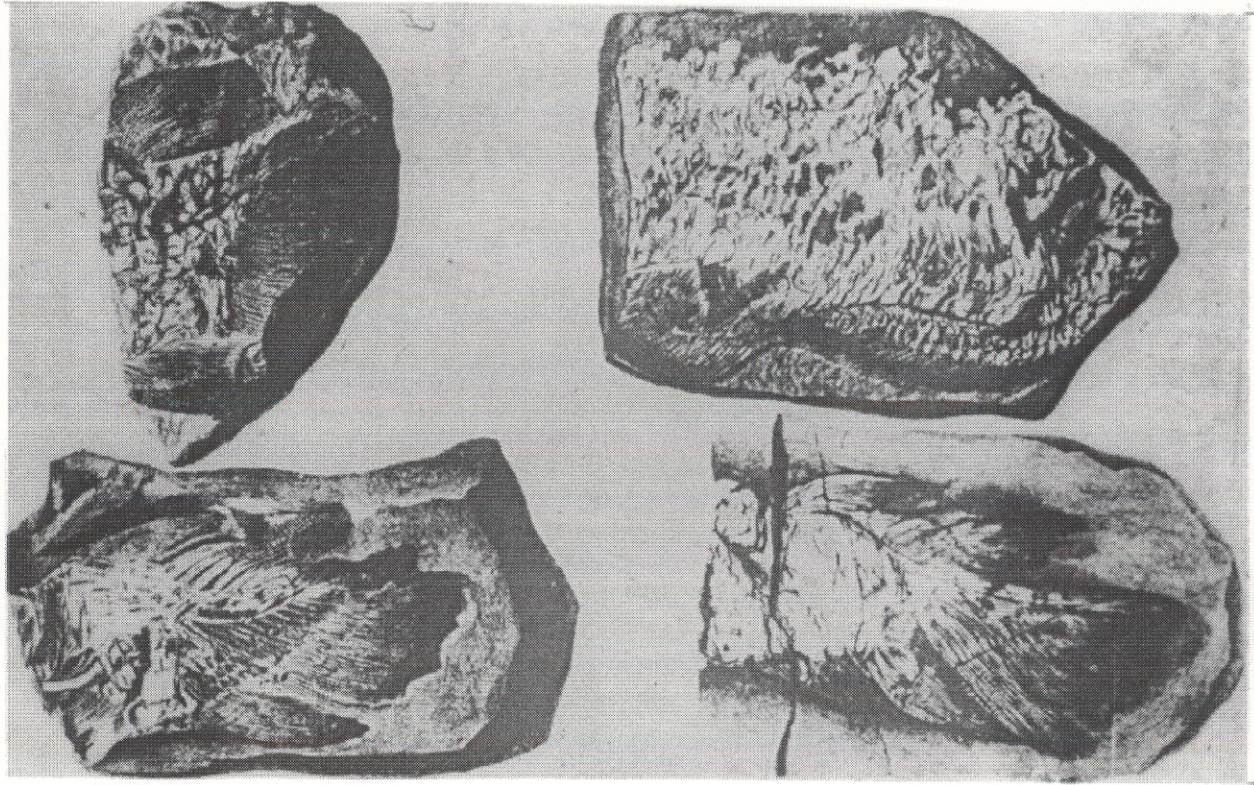
FIG. 78.



A, Homocercal tail; B, Heterocercal tail.

Now it is obviously the 'heterocercal' tail, which departs least from the 'archetype,' and we find that even those Fishes which present the 'homocercal' conformation in their mature condition, have their tails originally 'heterocercal.' Thus as the 'heterocercal' tail is the *most general* character of the class, being possessed by every fish at some period of its existence, whilst the 'homocercal' conformation is specially limited to a section of the class, the all-but-universal prevalence of the former during the earlier periods of the life of the class in our seas, and the comparatively late appearance of the latter, constitute a very remarkable example of this form of the doctrine above stated.—The Geological history of the

Illustrations of homocercal tails of modern fish and of ancient fish, representing Louis Agassiz's discovery; from Willim Carpenter, *Principles of Comparative Physiology* (1854)—Darwin's copy.



Fossils showing ganoid fish with heterocercal tails, from Louis Agassiz, *Monographie des poissons fossiles du vieux grès rouge, ou système Devonien* (1844–1845).

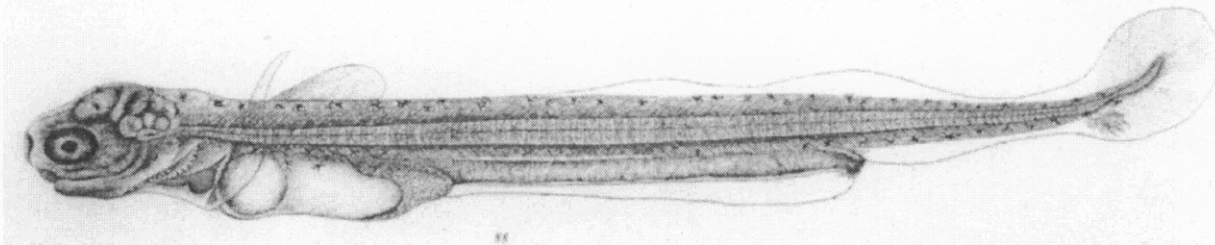


Illustration of salmon embryo with heterocercal tail, from Louis Agassiz and Carl Vogt's *Histoire naturelle des poissons d'eau douce* (1842–1845).

“I look at Owen’s Archetypes as more than idea, as a real representation as far as the most consummate skill & loftiest generalization can represent the parent form of the Vertebrata.”

Darwin’s copy of Owen’s *On the Nature of Limbs*, back flyleaf.

Darwin's Principle of Recapitulation

“As the embryonic state of each species and group of species partially shows us the structure of their less modified ancient progenitors, we can clearly see why ancient and extinct forms of life should resemble the embryos of their descendants—our existing species.”

Darwin, *Origin*, p. 449

The Principle of Recapitulation, 6th edition

“As the embryo often shows us more or less plainly the structure of the less modified and ancient progenitors of the group we can see why ancient and extinct forms so often resemble in their adult state the embryos of existing species of the same class.”

Darwin concludes concerning recapitulation

“Embryology rises greatly in interest, when we thus look at the embryo as a picture, more or less obscured, of the common parent-form of each great class of animals.”

Darwin, *Origin*, p. 450

Rudimentary Organ

1. Coccyx bone in humans, perhaps the appendix, vestigial wings in some beetles.
2. Blind cave fauna and burrowing animals (e.g., moles):



Chapter 14: Conclusion

He says he has produced “one long argument”

1. Lynchpin of his long argument—these facts which result in a conclusion that can’t be disputed (p 459)
 - a. That traits are variable
 - b. That traits heritable
 - c. That food supply is limited, while reproduction is vast
 - d. The consequence: struggle for existence
 - e. The consequence: differential survival
 - f. The consequence: slow alteration of the species
2. Objections:
 - a. Social insects
 - b. Sterility of hybrids
 - c. The lack of intermediate forms
 - d. Gaps in the fossil record

The Difference made in biology by an historical perspective

“When we no longer look at an organic being as a savage looks at a ship as at something wholly beyond his comprehension; when we regard every production of nature as one which has had a history; when we contemplate every complex structure and instinct as the summing up of many contrivances, each useful to the possessor, nearly in the same way as when we look at any great mechanical invention as the summing up of the labour, the experience, the reason and even the blunders of numerous workmen; when we thus view each organic being, how far more interesting, I speak from experience, will the study of natural history become!”

Darwin, *Origin*, p. 485-86.

“Now to the ascent of that steep savage hill
Satan had journeyed on, pensive and slow,
But further way found none, so thick entwined,
As one continued brake, the undergrowth
Of shrubs and tangling bushes had perplexed
All path of man or beast that passed that way ...
Thence up he flew, and on the Tree of Life,
The middle tree and highest there that grew,
Sat like a cormorant, yet not true life
Thereby regained, but sat devising death
To them who lived, not on the virtue thought
Of that life-giving plant, but only used
For prospect what, well-used, had been the pledge
Of Immortality.”

(Milton, *Paradise Lost*)

The Teleological Structure of the Origin

1. From the notebooks:

“My theory gives great final cause of sexes in separate animals: for otherwise there would be as many species, as individuals, . . . but we can see if all species, there would not be social animals, hence not social instincts, which as I hope to show is probably the foundation of all that is most beautiful in the moral sentiments of the animated beings. **If man is one great object**, for which the world was brought into present state.--& if my theory be true then the formation of sexes rigidly necessary.”

E Notebook, MS 48-49.

2. “To my mind it accords better with what we know of the laws impressed on matter by the Creator, that the production and extinction [of plants and animals] should have been due to secondary causes.”

Origin, p. 488.

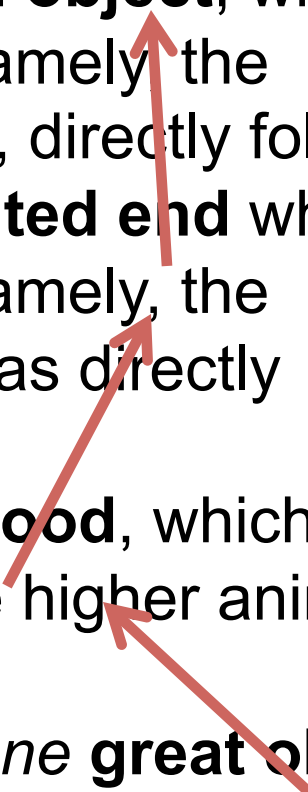
3. “And as natural selection works solely be and for the good of each being, all corporeal and mental endowments will tend to progress towards perfection.”

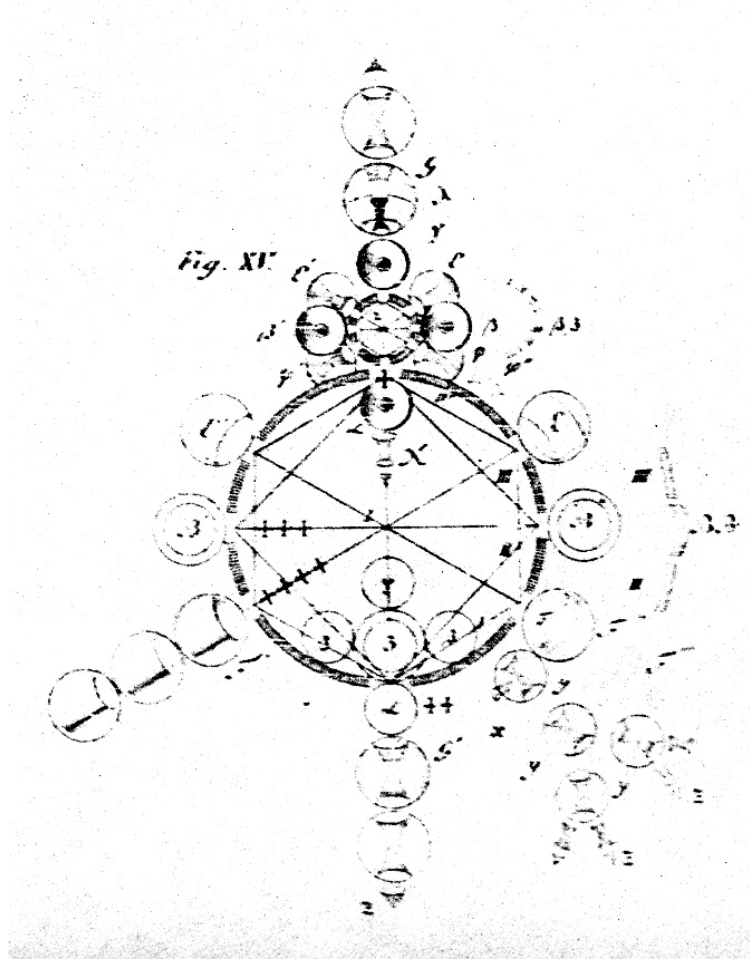
Origin, p. 489

“Thus from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely the production of the higher animals directly follows. There is grandeur in this view of life, with its several powers having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed laws of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved.” (*Origin of Species*, p. 490)

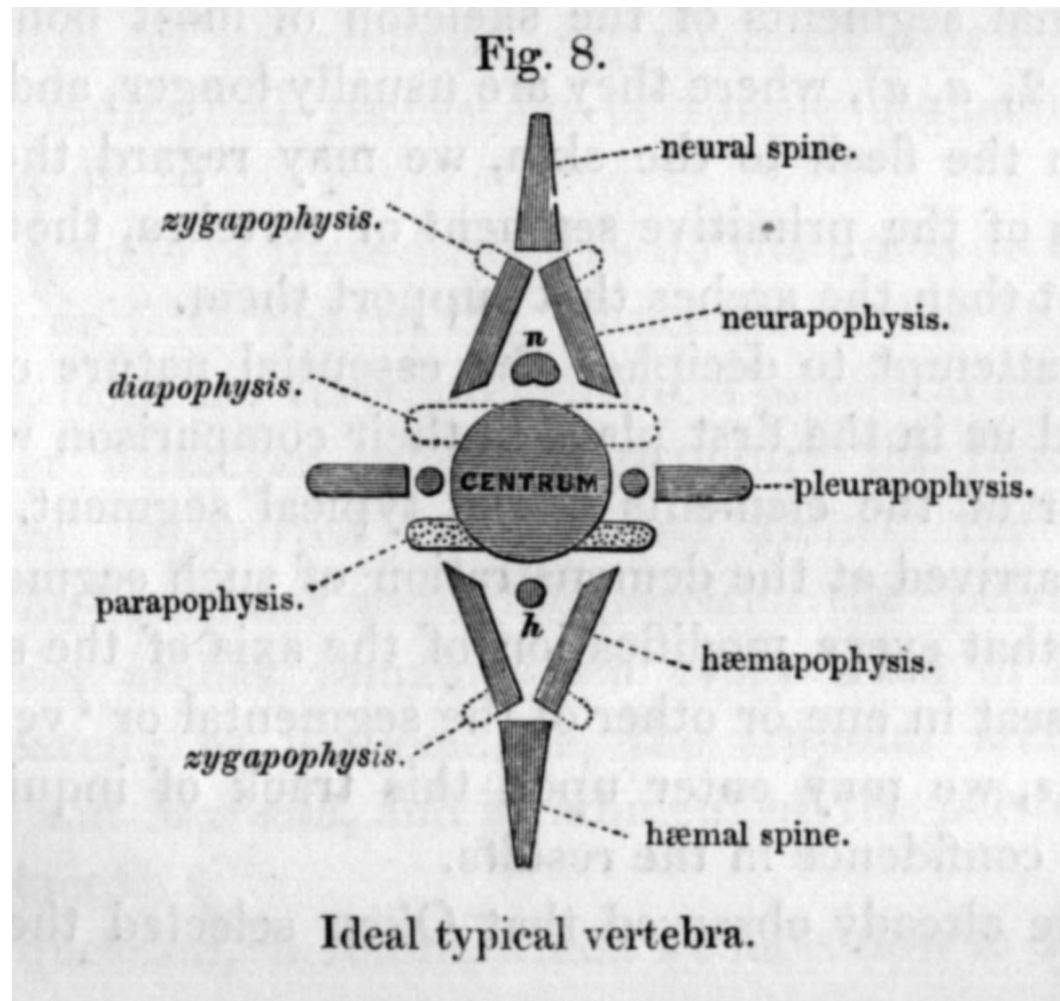
The Trajectory of Evolution

From the struggle for existence and natural selection,

4. 1859 (*Origin*): “the most **exalted object**, which we are capable of conceiving, namely the production of the higher animals, directly follows.”
 3. 1844 (Essay): “... the most **exalted end** which we are capable of conceiving, namely, the creation of the higher animals, has directly proceeded.”
 2. 1842 (Essay): “... the **highest good**, which we can conceive, the creation of the higher animals has directly come.”
 1. 1838 (*E Notebook*): “... man is *one* **great object**, for which the world was brought into present state.”
- 



The archetypal vertebra decompsed into spherical form ,
 from Carl Gustav Carus, Von den Ur-Theilen des Knochen
 und Schalengerüstes (1828).



The archetype as ideal vertebra, from Owen's *On the Nature of Limbs* (1849)



Tiktaalik rosea, about 375 million years old. Discovered by Neil Shubin, University of Chicago



A reconstruction of *Tiktaalik roseae*. Its fin contains incipient limb bones and its head swivels on its neck, unlike a fish.



Amphioxus: skull-less fish. A
presumed link from invertebrates
to vertebrates

