The Meckel-Serres Conception of Recapitulation [1]

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Johann Friedrich Meckel [5] and Antoine Etienne Reynaud Augustin Serres developed in the early 1800s the basic principles of what later became called the Meckel-Serres Law [6]. Meckel and Serres both argued that fetal deformities result when development prematurely stops, and they argued that these arrests characterized lower life forms, through which higher order organisms progress during normal development. The concept that the embryos of higher order organisms progress through successive stages in which they resemble lower level forms is called recapitulation. Meckel, a professor of anatomy at the University of Halle [7] in Halle, Germany, and Serres, a physician at Hôtel-Dieu de Paris in Paris, France, did not work together. Rather, in the late nineteenth and early twentieth centuries, their similar approaches, in which they compared the anatomy and embryos of different species so as to relate stages of embryonic development to the *scala naturae*, led other scientists to generalize their individual concepts into one general theory. The recapitulation ideas of Meckel and Serres became part of the mid-eighteenth century debate about how to explain morphological similarities between species.

The concept of *scala naturae*, or the great chain of being, had an early proponent in Aristotle [8], who worked in Greece four centuries before the common era. Aristotle's *scala naturae* arranged all organisms into a hierarchy based on the complexity of their form. Humans topped Aristotle [8]'s hierarchy. After Aristotle [8], various groups restructured the *scala naturae* to reflect God's place in creating the hierarchy of nature. In this new framing of the *scala naturae*, humans [9] maintained their position at the top of the earthly creatures because of their likeness to the Deity, but were placed under God and the Angels.

During the early 1800s, when Meckel and Serres first articulated their doctrines of recapitulation, many accepted the *scala naturae* as the main explanation for the large variety of species found on earth. Aristotle [8] had hinted at recapitulation, or the idea that embryos pass through the morphological stages of beings lower on the *scala naturae*. Following Aristotle [8], many scientists attempted to find examples of recapitulation in developing embryos, such as in the chick [10] (*Gallus gallus*). Meckel and Serres took these ideas of a *scala naturae* and recapitulation and applied them to their own embryological studies.

Meckel was born in 1781 in Halle, Germany. He grew up helping his father prepare specimens for the family's anatomical collection, and he became professor of anatomy at the University of Halle [7]. Meckel was meticulous in his comparative study of abnormal embryological specimens, which he collected from all over the world. During Meckel's lifetime, he wrote multiple treatises on comparative anatomy and in his 1811 text, *Beyträge zur vergleichenden Anatomie* (*Contributions to Comparative Anatomy*), Meckel outlines the idea that embryonic stages of higher forms recapitulate the forms of animals that reside lower on the great chain of being. Meckel used malformations, which he saw as the results of early terminations to development, to help support his theory of recapitulation. To do so, he compared the arrested organs from organisms high on the *scala naturae* to the normally developed organs of organisms lower on the *scala*. Meckel's method of comparison between higher and lower organisms enabled him to argue that the organs of the higher life forms developed through the stages of lower morphologies; thus, development mirrored the hierarchy of organisms within the *scala naturae*.

Serres, a physician at Hôtel-Dieu de Paris in Paris, France, worked with Etienne Geoffroy [11] Saint-Hilaire, a professor of zoology at *Muséum National d'Histoire Naturelle* (National Museum of Natural History) in Paris. Serres published two volumes of comparative work on vertebrate brains in 1821, for which he received an award from the *Académie des Sciences* (Academy of Sciences). Serres argued that the developing human brain progressed through the hierarchy of nature as it developed; at first it looked like the brain of a fish [12], then a reptile [13], then a bird, and lastly a general mammalian brain before finally settling into the form of a human brain. This order of brain development appeared to mirror the *scala naturae*. Serres argued that a formative force propelled the development of species, but the organisms in lower species had too little of the formative force to have their organs develop into the more complex organs found in higher species. For this theory, humans [9] are the most complex life form because they have the greatest amount of what some later called Serres' force.

In 1828 Karl Ernst von Baer, professor of anatomy at the University of Königsberg, in Königsberg, Germany, criticized the recapitulation theories of Meckel and Serres in his publication, *Über Entwickelungsgeschichte der Thiere. Beobachtung und reflexion* (On the Developmental History of the Animals. Observations and Reflections). Von Baer disagreed with the theory that Meckel and Serres had constructed to explain similarities in embryonic development across the animal kingdom. Von Baer opposed the strict linearity that Meckel and Serres embraced, which saw all organisms placed on a single chain of life. Instead, von Baer embraced the separation of the animal kingdom into four distinct archetypes, or fundamental body plans: the radiate, like the starfish [14]; the mollusca, like clams and octopus; the articulate, likeinsects [15] and lobsters; and the vertebrata, like fish [12] and humans [9]. He classified organisms into each of the four archetypes according to how those organisms developed from embryos. Von Baer reasoned that because animals could be divided into four archetypes, embryos could not recapitulate all lower forms throughout their development. Instead, von Baer argued that embryos appeared similar to their archetype at the beginning of development, and grew more specialized over time. Von Baer's account of the relationship between development

and the natural hierarchy of animals, articulated in his 1828 text, formed the basis of what later scientists called von Baer's Laws [16].

Following public dismissal by von Baer and by Richard Owen [17], Hunterian Professor at the Royal College of Surgeons, in London, England, the recapitulation ideas of Meckel and Serres fell out of favor among scientists beginning in the late 1830s. In 1859, Charles Darwin [18], who worked mainly at his country estate near Kent, England, argued for the theory of common descent among species in his book, *On the Origin of Species*. Darwin's book prompted Ernst Haeckel [19], professor of comparative anatomy at the University of Jena [20], in Jena, Germany, to resurrect the main points of Meckel and Serres.

Haeckel's new iteration of Meckel's and Serres' ideas of recapitulation, for Haeckel called the biogenetic law [21], abandoned the explicit connection to the *scala naturae*. Instead, Haeckel embraced Darwin's theory of common descent as the framework that unites all organisms. The biogenetic law [21] connected the study of embryonic development, called ontogeny [22], with the study of the relationships of descent between species, called phylogeny [23].

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Subject

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