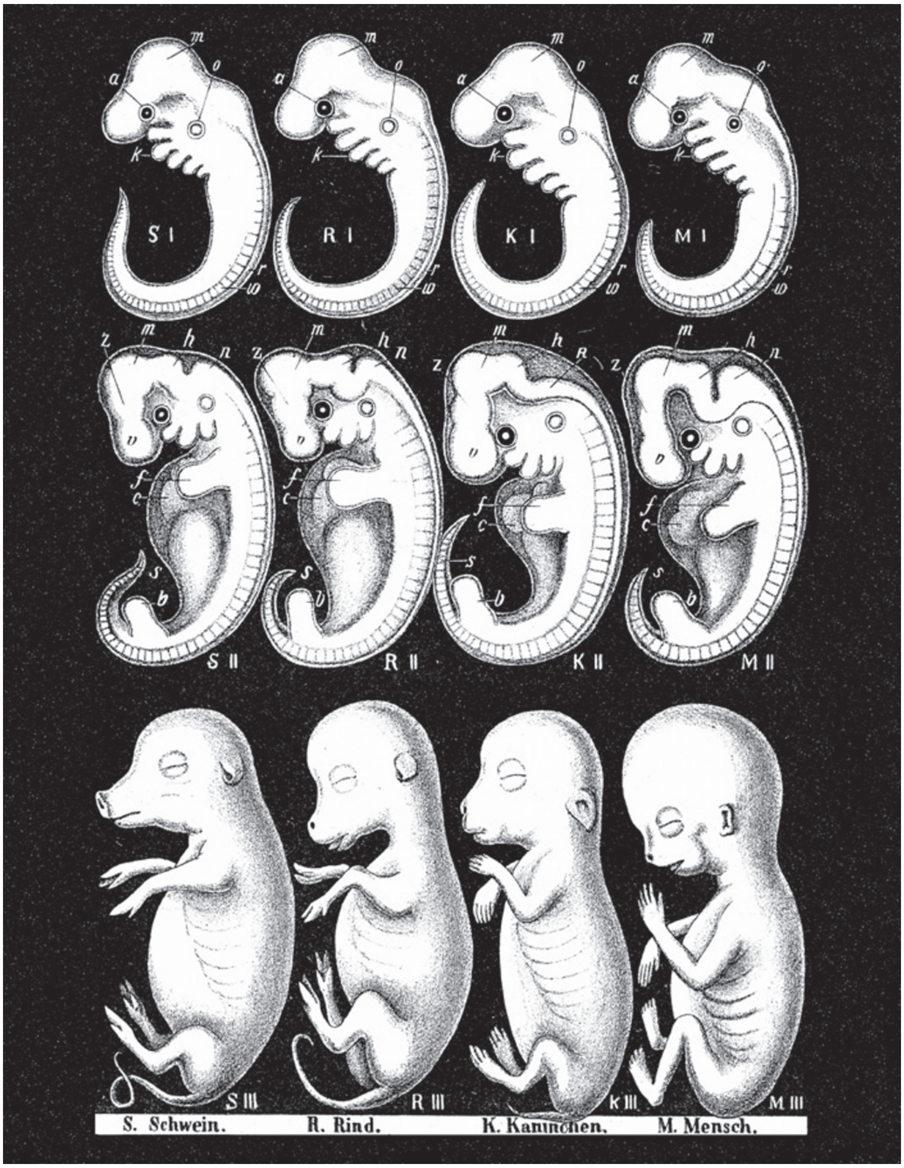


IAM/AKG-IMAGES

Ernst Haeckel's 1874 drawings track embryo development in pigs, cows, rabbits and humans.

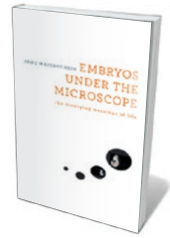
DEVELOPMENTAL BIOLOGY

Life in flux

Renee Reijo Pera enjoys a treatise tracking the rise of embryology, from Aristotle to cloning and beyond.

Since the advent of *in vitro* fertilization (IVF) in 1978, embryology has rarely left the headlines. From cloning to regenerative medicine to legal wrangles over stem cells and mitochondrial DNA replacement, the science of how and when human life begins has a powerful fascination. In *Embryos Under the Microscope*, Jane Maienschein reminds us that we have always argued about those questions.

Her fascinating tour of them is a balanced combination of history and science. We track the thoughts of philosophers Aristotle and Descartes; follow the development of modern experimental embryology by scientists such as Frank Lillie; and examine the twentieth- and twenty-first-century focus on understanding the molecular and genetic contribution of the sperm, egg and embryo to the offspring. Through this, Maienschein — director of the Center for Biology and Society at Arizona State University in Tempe, and of the centre's Embryo Project — interweaves the science of embryology and the many controversies that it continues to spark.



Embryos Under the Microscope: The Diverging Meanings of Life
JANE MAIENSCHEIN
Harvard University Press: 2014.

The embryo, the product of the fusion of sperm and egg, was hypothesized from ancient times. Proponents of epigenesis strongly believed that human life begins gradually, and that the individual arises *de novo* from potent materials. In the fourth century BC, Aristotle became one of the theory's earliest supporters. He was aware of some 'facts of life', such as that the menstrual cycle was linked to reproduction and that sexual intercourse involved the mingling of male and female fluids. An observer and biologist at heart, Aristotle watched chick embryos develop, seemingly from amorphous materials to a recognizable form that emerged on hatching. As Maienschein makes clear, he instinctively understood that what he observed might be relevant to humans and other animals. Aristotle's ideas illustrate the scientific method at its best, in the face of great unknowns. Without the benefit of microscopy, he put forth concepts regarding the earliest stages of development that survived for more than 1,500 years.

The theory of preformation emerged in the seventeenth and eighteenth centuries along with microscopy. It posited that a preformed individual was present at conception but hidden from view, requiring activation. The advent of microscopy allowed scientists such as Caspar Friedrich Wolff and Charles Bonnet to see the earliest stages of development in many animals. This shifted embryology from a largely philosophical field to an experimental one. The earliest stages of species including the chicken, frog, dog and rabbit were examined.

As Maienschein describes, embryology grew by leaps and bounds in the nineteenth century. Karl Ernst von Baer drew elegant pictures of chick-embryo development, and Ernst Haeckel compared the development of multiple organisms, concluding that perhaps "ontogeny recapitulates phylogeny" — development of the individual repeats the evolutionary history of the group or species. In 1895, cell biologist Edmund Beecher Wilson published *An Atlas of the Fertilization and Karyokinesis of the Ovum*, documenting many aspects of fertilization and oogenesis and suggesting that in diverse organisms, the same types of cell may give rise to the same structures.

Concurrently, genetics and developmental biology emerged from embryology ▶

as scientists sought to explain how development might be linked to chromosomes and heredity, as outlined in studies by Theodor Boveri and Walter Sutton. Further research by embryologist Hans Spemann and others probed how tissues form and what drives cells to develop into different kinds. In recent decades, researchers have been able to genetically modify organisms, track developmental fate and sequence DNA to find naturally occurring variants (insertions, deletions and even single-base-pair mutations) that affect embryo development in flies, fish, frogs, worms, mice and even humans.

Findings in embryology led to a transformation in reproductive medicine with the advent of IVF through the work of Patrick Steptoe and Robert Edwards in 1978. With that came a new focus on the value of human life, from the earliest stages and throughout pregnancy. Concerns burgeoned, leading in the United States to the Dickey–Wicker Amendment of 1996, which prohibited the use of federal funds for research that would create or destroy human embryos. Controversies intensified around cloning technology, beginning in 1997 with the work of Ian Wilmut and his team on Dolly the sheep, and continuing in debates on the ethics of research into human embryonic stem cells and their potential in cell-based therapies for regenerative medicine.

Embryos Under the Microscope does have gaps. It lacks material regarding epigenetic reprogramming — the establishment of DNA and histone-protein modifications in the early embryo that allows embryonic cells with identical DNA sequences to generate diverse cell types — which is a central event in embryology. Yet Maienschein covers broad territory with surprising depth and concision. It seems unlikely that a more readable text will soon emerge to illuminate the journey from theory to observation to ethical considerations in this exciting science.

Lines from T. S. Eliot's 1942 poem *Little Gidding* from *Four Quartets* resonate here: "And the end of all our exploring/Will be to arrive where we started/And know the place for the first time." We have made remarkable progress in our wonderful journey to understand the origins of our development. ■

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JADE HOFFMAN/NATURE

Daniel Jones in Thetford Forest, UK, the first location for his installation *Living Symphonies.*

Q&A Daniel Jones

Canopy composer

Sound artist Daniel Jones creates self-generating artworks based on human and natural patterns and processes. As he prepares to travel through four UK forests with the installation Living Symphonies, *a collaboration with artist James Bulley, he talks about music that emerges from ecosystem dynamics, and works inspired by bacterial genetics and social networks.*

What is *Living Symphonies*?
It is an ever-changing piece of music that grows in the same way as a forest ecosystem, from the interactions of countless tiny elements. Each reflects the activity of an individual organism, ranging from moss and fungi to deer and birds of prey. The outcome is an organic, emergent symphony comprised of thousands of musical motifs, each portraying a different aspect of the ecosystem.

How do you build each forest installation?
We start with a survey of the animals and plants. We add behavioural insights from ecologists: what times of day is a blackbird active and foraging, how does it move, what are its preferred food sources? We feed this information into a computer model of the ecosystem (programmed in C++ with the Cinder visualization library) that simulates the second-by-second interactions between species. This model is linked to a custom piece of audio software that orchestrates music in real time from a vast array of motifs representing each species. The music is played through a network of speakers in the canopy and undergrowth.

Living Symphonies
DANIEL JONES AND JAMES BULLEY
Next at Thetford Forest, 24–30 May 2014.
www.livingsymphonies.com

How does the composition sound?
The motifs for each organism are drawn from fragments that we composed and recorded with orchestral musicians. Our goal is a work with such a great number of interdependent elements, in a nearly infinite combinatorial space, that even we are surprised by the patterns and permutations that arise. This 'emergent' approach runs through all of my work. Emergent phenomena pervade economics, ecology, linguistics and neuroscience; examples include the flocking of birds, and the interactions of neurons that give rise to cognition. By translating the dynamics of a forest ecosystem into music, *Living Symphonies* aims to heighten awareness of the adaptive and often creative behaviours of these complex systems.

Have any animals responded to the piece?
When we ran our first forest prototype last autumn, there was some worry that it would scare off the wildlife. Yet when we