BOOKS & ARTS

Evolution's challenge to genetics

Do conjoined twins and two-legged goats suggest a minor role for genetics in evolution? The evidence is not strong enough to upset the orthodox view, argues **Jerry A. Coyne**.

Freaks of Nature: What Anomalies Tell Us About Development and Evolution
by Mark S. Blumberg
Oxford University Press: 2009. 344 pp.
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Darwin200

In 1980, an evolution meeting at the University of Sussex, UK, featured several speakers who questioned the importance of genetics in understanding evolution and development. The 'structuralists' saw the adaptations of many organisms as products of self-organizing molecules rather than natural selection. Others touted the epigenetic view, claiming that important evolutionary change involved heritable features not coded in the DNA. Perturbed, the distinguished embryologist Lewis Wolpert stood up and proclaimed that he too had a radical and heretical view: "Genes control development." Wolpert was puckishly defending what he saw as a perfectly adequate paradigm against those who minimized the importance of genes. To emphasize his point, he switched the lights on and off during the coffee break — but the structuralists refused to admit that the switch controlled the lights.

The past three decades have vindicated Wolpert. Virtually all of the major advances in evolutionary developmental biology, or 'evo-devo', have been firmly grounded in genetics. These include studies — two of them awarded a Nobel prize — on how genes organize body plans, how genes are regulated and how the same genes, such as *PAX6*, are recruited in the independent evolution of similar structures in different species.

But as evo-devo blossoms, the anti-genetics strain persists. Evo-devo is undergoing the kind of spasm experienced by palaeontology when Stephen Jay Gould and others decided that their field had been overlooked in the modern evolutionary synthesis, or worse, forced to conform to the theories of population geneticists and others at the heart of the synthesis. Gould suggested that palaeontology, when uncoupled from its overbearing cousins, would provoke a major revision of our understanding of the evolutionary process. Gould was wrong: the neo-Darwinian perspective emerged unscathed from its encounter with punctuated equilibrium. Now it is the turn of evo-devo to challenge neo-Darwinian orthodoxy. As Mark Blumberg declares in *Freaks of Nature*, evolutionary biology should not just describe developmental phenomena, but should also incorporate new evolutionary processes that de-emphasize the role of genetics.


UPPA/PHOTOSHOT

It is difficult to see how developmental quirks are relevant to evolution — even if you have two heads.

By presenting a parade of animal 'freaks' — mutants, developmental anomalies and weird species — Blumberg imparts lessons that, although familiar to biologists, will be valuable to non-specialists. He emphasizes that the complex process of development can be unravelled by understanding how such anomalies are produced. Conjoined twins, for example, tell us something about how identical twins form. He highlights, correctly, that there is no direct correspondence between genes and traits: there is no such thing, for example, as the gene for the thumb, although some mutations can create new thumbs. He also stresses that evolution can work only by modifying development, and that natural selection can create individuals whose development responds adaptively to the environment — as in the case of rotifers, some species of which develop spines in response to predators.

Blumberg illustrates his points with clear and intriguing examples. We learn that female hyenas lack vaginas but have huge, penis-sized clitorises through which they copulate and give birth, often resulting in high infant mortality. We meet Abigail and Brittany Hensel, 18-year-old conjoined twins from Minnesota — two heads on a single body — whose touching story can be seen on YouTube (see http://tinyurl.com/26bpm9). And we discover that the nervous system of rabbits can be entrained to make them walk rather than hop, implying that hopping is not genetically encoded but a by-product of the rabbit's leg structure.

Blumberg's ambitions transcend storytelling: he aims to show that developmental biology has made real contributions to evolutionary theory. The theory's problem, as Blumberg maintains, is its "gene-centered, population-level thinking", also described as "simplistic single-cause, gene-centered thinking". What paradigms, then, should supplant our misguided embrace of Gregor Mendel?

The first is epigenetics. Blumberg notes that larger male dung beetles roll larger balls of dung, which in turn nurture larger sons. He argues that "Such examples of nongenetic transmission of characters are now becoming commonplace and are helping solidify the notion that the heredity upon which evolution depends is more than just about genes." But we must be careful. Some adaptive 'epigenetic' phenomena, such as parental imprinting of chromosomes, which influences gene expression depending on which parent passed on the gene, are based on instructions in DNA. Other

cases of epigenesis, such as the conformational changes of prion proteins, are of minor evolutionary significance. Still others, such as an ancestral cell's ingestion of the bacteria that evolved into mitochondria, were of immense importance in evolution but are infinitely rarer than adaptive changes based on genes. And in nearly all cases, epigenetic effects peter out after a few generations, unable to promote major evolutionary change. Perhaps the most serious criticism of epigenetics is that of the thousands of inherited mutations found in model organisms such as mice and fruit flies, virtually all reside in DNA.

The second paradigm involves "the self-righting properties of developmental systems", also known as phenotypic accommodation, which, says Blumberg, lead to evolutionary innovation. To support this, he trots out the two-legged goat described in 1942 by Dutch veterinarian E. J. Slijper. The goat, a developmental anomaly born without forelegs, learned to hop on its hindlimbs like a kangaroo. When the goat died in an accident — some say in an ill-advised experiment to see if it could walk downstairs — Slijper's autopsy showed that it had undergone modifications of its spine, hindlimbs, muscles and neck that facilitated its bipedal hopping. It has been suggested that this hobbled beast is a model for the origination of bipedality in some lineages, even humans. Although Blumberg admits that this is unlikely — after all, there are perfectly good, and more parsimonious, Darwinian explanations for bipedality — he approvingly quotes anatomist Pere Alberch: "The regulatory capacities of an epigenetic system imply that any intrinsic change will trigger a sequence of regulatory changes to automatically generate an integrated phenotype." But as this integrated phenotype was not based on genetic differences from any other goat, it could not be transmitted to offspring, and its relevance to evolution is unclear. The phenotypic changes in Slijper's goat did not result from some inherent self-regulating property of development. Rather, they reflect an evolved phenomenon: natural selection has given bones and muscles the adaptive property of developing in response to the stresses they experience.

Blumberg's final alternative to conventional evolution is genetic assimilation. As with phenotypic accommodation, here the phenotype changes before the genes. During assimilation, an initial environmental change alters the phenotype of many individuals, exposing previously hidden genetic variation that can then be selected. Eventually, what was an environmental change becomes genetic, mimicking the inheritance of acquired traits.

Social learning is one way to start this process. For example, in the 1920s, two species of British tits learned by mass imitation to pry up the foil on milk bottles and drink the cream on top. Were home milk delivery still common, one can imagine that this propensity might have become genetically assimilated. Individuals with greater abilities to learn the behaviour, or perform the actions needed, would be favoured by selection. Eventually, cream pilfering would become innate — coded in the genes. Many adaptations might have started in this way; fish, for example, may have evolved adaptations for living on land after some individuals discovered terrestrial insects to be a rich food source. But we can also explain such cases by invoking simple selection on pre-existing genetic variation. In the absence of a single credible example of genetic assimilation in nature, it remains an appealing but untested speculation.

In the end, the problem with these explanations is not so much that they are wrong, or of no potential importance in evolution. Rather, it is that Blumberg gives the impression that they are established truths rather than hypotheses that have remained unconfirmed for three decades. In his anxiety to boost the status of evo-devo in the pantheon of evolutionary subdisciplines, Blumberg has short-changed orthodoxy. Not only does the traditional view of evolution explain far more than he allows, but Blumberg shapes his own vision of development to inflate its challenge to neo-Darwinism. I, for one, am with Wolpert. ■

Jerry A. Coyne is a professor in the Department of Ecology and Evolution at the University of Chicago, Illinois 60637, USA.
e-mail: j-coyne@uchicago.edu

The future is now

"With great power comes great responsibility," uttered Stan Lee's comic-book superhero Spider-Man in his first published appearance in *Amazing Fantasy* in 1962. Since then, science has advanced to such a point that the human body can be enhanced in ways that mimic fiction. Cloning, face transplants, prosthetic limbs, brain–machine interfaces and cognition-enhancing drugs promise utopian or Orwellian visions of the future, depending on your outlook. It is the scientific community, not the superhero, that holds the great responsibilities of our age and the next.

Two books, *Human Futures* and *The Science of Heroes*, use a crystal ball to imagine how science will determine the future of human existence and society.

Human Futures is a varied collection of meditations on the notion of humanity from researchers, artists, philosophers and even a Blood Elf priest from the online role-playing game *World of Warcraft*. The book is born of the Human Futures programme of the Foundation for Art and Creative Technology, based in Liverpool, UK. The programme comprised a series of exhibitions and lectures for public debate, in which creative assemblages of artists, philosophers and scientists explored questions of what we are now, and what we will become.

The first of the book's four sections, entitled 'Visions', perhaps best succeeds at describing the problems of the future using intelligent insights from the present. Many of the essays focus on society's willingness, or not, to embrace new technologies. Philosopher Russell Blackford argues convincingly that a fear of new technologies is groundless and erodes liberalism. He notes that a governing state can allow new advances, such as choosing the sex of one's child, without endorsing the underlying technology or morality of an individual's choice.

The concept of human enhancement is investigated by ethicist Ruud Ter Meulen. Certain drugs such as modafinil, used to treat narcolepsy, have been shown to improve cognition and are becoming increasingly popular with students revising for exams. If everyone takes the drug in future, then what is the new norm? Will it make us better, or just different?

Physicist Richard Jones asks how humans have been enhanced by technology. He observes that the public accepts the benefits of gadgets while increasingly rejecting the scientific world view. As a result, he explains, per capita energy use in the United Kingdom has risen from 20 gigajoules per person in 1800 to nine times that figure today. Life expectancy, he notes, is strongly correlated with energy use. Such a rise in energy use looks unsustainable at present, but Jones asserts that technology is a product of society, not a runaway automaton, and solutions will come as long as the energy flows.

Oddly, the section concludes with a delightful

Human Futures: Art in an Age of Uncertainty
Edited by Andy Miah
Liverpool Univ. Press: 2008. 368 pp. £35

The Science of Heroes: The Real-Life Possibilities Behind the Hit TV Show
by Yvonne Carts-Powell
Berkley Boulevard Books: 2008. 288 pp. $15