nature cell biology

Darwin's legacy

The double anniversary of Darwin's bicentenary and 150 years since publication of *On the Origin of Species by Means of Natural Selection* provides the perfect pretext to enhance the public understanding of evolution.

Charles Darwin, who was born 200 years ago this month, published his collected thoughts on the evolution of life three months before his 51st birthday. The intervening nine months are packed with events in many countries on the scientific and philosophical implications of what is unquestionably the most important concept in biology (www.darwin200.org; www.darwinday.org; his alma mater Cambridge University follows up on its 1909 celebrations (www.darwin2009.cam.ac.uk); *Nature* (www.nature.com/news/specials/darwin); *Science* (www.sciencemag.org/darwin)).

The fact that evolutionary theory is now so well-supported experimentally and widely accepted makes it hard to appreciate the insight and intuition required at the time to formulate a theory that has survived essentially unchanged for 150 years. Consider that Darwin, and independently Alfred Russel Wallace, observed variation almost a hundred years before DNA, its molecular basis, was identified as the universal genetic material, and long before mutagenesis and meiosis were described (although notably, Gregor Mendel published almost concurrently with Darwin in 1866). Only very recent technological advances have allowed us to systematically decipher the primary changes that underlie evolution, and to understand how these changes are transformed by developmental processes into the phenotypic variation of form and function observed by Darwin. It was truly a milestone when Darwin and Wallace appreciated that all life forms are linked by common ancestry and that life's form is mutable and shaped by selection and competition.

Natural scientists at the time were obviously less specialized; nevertheless, it is remarkable how Darwin integrated the relatively new science of paleontology with zoological and botanical observation, providing him with both the natural history and live evidence for phenotypic change and natural selection (it should be emphasized that others contributed to Darwin's great synthesis of thought; for example, paleontologists, including Charles Lyell, had already described sequences of fossil forms in the geologic record in 1833). Evolutionary theory has had a major impact not only on paleontology, zoology, botany and ecology, but also on population and molecular genetics, and developmental biology. In today's era of unavoidable hyperspecialization, the field-bridging nature of Darwin's approach and theory serves as a reminder of the value of cross- and multi-disciplinarity. Genomics, proteomics, systems biology and quantitative cell biology would not be progressing so rapidly without input from physical scientists and mathematicians. Thankfully, funding agencies are increasingly supporting trans-disciplinary research.

Another interesting aspect of Darwin was his ability not to let his Christian faith dominate or undermine his evidence-based research. One year after first presenting it jointly with Wallace at London's Linnean Society, he bravely publicized his theory, which he knew would be perceived to be at odds with Church doctrine. One would hope that Darwin's ability to reconcile evolution with his faith will serve as a reminder to dogmatists on both sides that a religion able to absorb new ideas and insight can co-exist with science.

The impact of evolution is all-pervasive at the level of cell and molecular biology. The rapid emergence of microbial drug resistance remains a compelling demonstration of evolution in action. Recent reports have also documented the molecular basis of toxin resistance in soft-shell clams and even garter snakes. The short life cycles of microbes have helped uncover other interesting facets of evolution, such as stress-induced adaptive mutagenesis, where the DNA damage response accelerates evolutionary rate under unfavourable environmental conditions. The study of the evolution of developmental process has spawned a sizeable research community under the umbrella term 'evo-devo'. A key concept emerging is that evolutionary conservation is much more apparent at the genetic level than the developmental level. In other words, genetically stable building blocks assemble related phenotypes through a surprising variety of developmental pathways in different species. This has important implications for biologists who extrapolate observations from model organisms to human biology and who typically work in a reductionist way by changing one component at a time to study its physiological role. Many other evolution-flavoured concepts have emerged in developmental biology recently, such as the role of the chaperone Hsp90 as a capacitor — or buffer — for morphological evolution in *Drosophila* and *Arabidopsis* (although it potentiates evolution of new traits in fungi). Cell competition in *Drosophila* imaginal discs provides a cellular example of natural selection by competition in a closed system (the tissue): a cell with a viable but growth inhibiting change is not only outgrown by its neighbours, but also destroyed by them. This mechanism seems to occur in mammals and may have implications for tumour development. Adaptive systems are also apparent in the clonal expansion of antigen-stimulated lymphocytes and possibly cancer cells. Models for selective processes that shape neural connectivity in the brain have been called 'neural Darwinism'.

Gratifyingly, the mechanistic underpinning of many physiological processes with evolutionary connotations is being uncovered; for example, the calcium signalling molecule calmodulin may underpin the variation Darwin observed in the beaks of Galapagos finches. Evolution of the eye is widely cited by supporters and detractors of evolution alike; a few months ago a paper dissected the mechanism of sensory-motor coupling in plankton phototaxis, which resembles Darwin's 'proto-eye'. Indeed, we are on the verge of bypassing evolution altogether in the lab: our understanding of basic biological processes is now such that the first attempts at synthetic biology are under way, with plans to reverse natural selection by cloning extinct species such as the mammoth.

Evolutionary theory has been dramatically validated by molecular biology. It is important that the general public, and in particular pupils, hear and understand this message (see www.nature.com/evolutiongems for a sample of scientific papers that illustrate and buttress evolutionary theory). Redressing the current imbalance between increasingly well-organized and vociferous religious fundamentalists peddling creationism, and scientists, who all too often disregard the need for further publicity and support for what is, after all, the best supported theory in biology, should be high on the agenda of every scientist and science teacher. Why not make this a New Year's resolution for 2009, Darwin's year.