Commentary

Ernst Mayr and the complexity of life

On August 2, 2005, President Bush stated publicly that he favours that Intelligent Design be taught side by side with the Theory of Evolution in science classes, since he believes that the complexity of organisms can be explained best as having been created by an Intelligent Being (e.g. Bumiller 2005). While Intelligent Design has been promoted by a powerful political machine (e.g. Alter 2005; Anonymous 2005; Krugman 2005), for the American public there may be more weighty consequences in these utterances of a president seemingly making a plea for a balanced curriculum. As it is, the words 'scientific' and 'science' have lost much of the absolute credibility they enjoyed in the 19th and 20th centuries, and fewer and fewer students choose to become scientists and engineers. The President's remarks will only embolden political powers to meddle even more in science education and, thus, undermine science's mission to free humanity from superstitions, fallacies, and misconceptions.

Only six months earlier (on February 3, 2005), biology lost a towering figure in Ernst Mayr, the last surviving contributor to the Synthetic Theory of Evolution, also called 'Neo-Darwinism'. On this occasion, innumerable obituaries (e.g. Bock 2005a; Bradt 2005; Haffer 2005; Sullivan 2005; Unwin 2005; Yoon 2005a, b) supplemented the memorials that had been published on the occasion of his centenary last year (e.g. Bock and Lein 2005). Did all this publicity for the Theory of Evolution fall on deaf ears? Would the public's (and the President's) understanding of the centrality of the Theory of Evolution in modern life be greater if Nobel prizes could be awarded to evolutionary biologists and had Ernst Mayr been awarded one of them? Or would evolutionary biology be more valued among the scientific disciplines, if the Balzan Prize for Zoology and the Crafoord Prize (Bock 2005b) and the International Prize for Biology (Mawatari 2005), which Mayr did win in 1983, 1999 and 1994, respectively, were better known as the "alternative Nobel prizes" for biology and received media treatment comparable to that given to 'real' Nobel prize-winning disciplines?

Mayr was perhaps best known as a relentless explainer and defender of "population thinking" and a foe of "typological thinking" or 'essentialism'. As a naturalist by inclination and training, he was all too aware of the intrinsic individual variations within a population, which occasionally are even more significant than variations between populations or even between species [see, for example, the very similar sibling species of the Chiffchaff (*Phylloscopus collybita*) and the Willow Warbler (*Phylloscopus trochila*) in Europe]. When Mayr was a student in Germany, the problems of how to delimit species and 'races' (i.e. subspecies) and how to explain their evolutionary history were part of the "hot topics" in biology. Not quite surprisingly at a time when the study of the genetics of wild populations was still in its infancy, Lamarckian processes were seriously considered as a possible explanation for the origin of distinct populations that were clearly adapted to their environment (Mayr 1980; Mayr and Provine 1980), such as the lighter coloured coats and plumages of populations living in arid habitats in comparison to those of populations living in humid, vegetated habitats. Mayr (1980, 1982) later pointed out the role of Lamarck's ideas as early evolutionary hypotheses and how seamlessly Lamarckian ideas could be supplanted by Darwinian ones.

Mayr's voyage to New Guinea and the Melanesian Islands, following the completion of his doctorate, presented him with the opportunity to encounter 'genuine' biodiversity in all its complexity, a life-changing experience for every European-born and European-trained biologist, as it was for Alexander von Humboldt, Adalbert von Chamisso, Alfred Wallace, and Charles Darwin before him, to name only a few. It is one of the ironies of history that scientific biology was developed in Europe, which happens to be one of the biologically more depleted and impoverished continents due to a combination of its past ice ages, temperate climate, and dense human population. One of the most striking experiences for a European-trained ornithologist in the tropics is the much brighter and more colourful avifauna compared to the subdued and drab colouration of European birds. Mayr's training in the preparation of museum skins, which is the most reliable and convenient long-term preservation method for bird specimens, in combination with his keen eye, prepared him well for collecting the data necessary for describing the multitude and multiplexity of the avifauna that had evolved in the geographically complex Melanesian environment (e.g. Mayr and Diamond 2001). In this environment, he was able to correlate often subtle differences in size, colour pattern, and behaviour with clearly delimited geographical regions, such as islands, or areas that are isolated by mountains or rivers or by differences in altitude and climate (Mayr 1933, 1940; Vuilleumier 2005).

After Mayr had moved to New York City and assumed his position as curator at the Department of Ornithology of the American Museum of Natural History, he met Theodosius Dobzhansky who became a professor of genetics at Columbia University in 1939. The developing collaboration and personal friendship between these two great biologists must be considered one of the fortuitous coincidences that tend to be crucial in so many major advances in the history of science. Dobzhansky had been trained in Russia in a tradition that integrated modern genetics and natural history. Mayr and Dobzhansky, therefore, shared a common interest in natural history, but complemented each other through Mayr's experience in the tropics and Dobzhansky's work in genetics (Mayr and Provine 1980).

Mayr's subsequent work dealt in one way or the other with disentangling and explaining the complexity that emerged from the fact of biological variability at the levels of individuals, populations and species. In this endeavor, he was aided by the premise that organisms are the entities that are the units of life (i.e. "in-dividuals" that are indivisible), similar to what atoms in physics and chemistry used to be (i.e. "a-toms" that cannot be cut into smaller parts and, hence, are indivisible). The individual organisms drive natural selection and, thereby, evolutionary change through their interactions with their environment and among themselves. These interactions, however, are complex, usually involving various and multiple aspects of an individual in complex movements and processes. This level of complexity below the organismal level was considered neither by Mayr nor by Darwin before him, probably because it is not immediately relevant to the questions they pursued, but also undoubtedly because, by inclination and training, both Darwin and Mayr were naturalists, not morphologists. Both Darwin and Mayr started their university studies in medicine, only to abandon them in favour of research in biology and natural history. The manner how budding scientists choose a discipline is an area of study that deserves more attention, but at least in the disciplines of natural history and systematics on the one hand, and of morphology and comparative anatomy on the other, it appears that these two broad fields of study attract different people who ask different questions (Homberger 2000).

Complexity in science has generally been approached by simplifying or 'reducing' it so as to make it more amenable to scientific enquiry. This analytical 'reductionistic' approach has yielded spectacular results, most notably in physics, chemistry, and molecular biology (Mayr 1997), and biologists, including evolutionary biologists and systematists, have used it as what they have long believed to be 'the' scientific method. To understand the interactions between individuals and their environment and their roles in evolutionary processes, particular features (e.g. beak shapes, body sizes or proportions, feather structures or colours, or vocalizations) that differ among populations are used as criteria to classify individuals into distinct groups (see, for example, Grant 1986). The hierarchical arrangement, or classification, of such groups, or taxa, has generally been guided by an assessment of the distribution of features across taxa (e.g. the Order Carnivora is characterized by specialized canine and carnassial teeth, the Family Felidae by a shortened face, and the genus *Felis* by retractable claws on the front paws). One long-standing problem, however, used to be the identification of the taxa at the species-level as opposed to those at the population- or genus-levels. As a naturalist, Mayr realized that biological criteria that are relevant for the process of evolution would be preferable for the delimitation of species taxa than would be morphological criteria, and his biological species definition posited that species are reproductively isolated from one another in contrast to populations, which are not (Mayr 1996). In practice, however, most species taxa are still delimited by their unique morphological features, not because it is the biologically correct thing to do, but because it is the next best thing as long as the reproductive biology of so many species is still unknown.

Features that are relevant for classification have generally also a genetic basis, and molecular characters at a certain level can be identified and compared in much greater numbers and at greater speed than morphological features and, in addition, without the need for life-long training for attaining a certain proficiency. This may have been the reason why Mayr in the late 1970's was very taken by the promises of biochemical, or molecular, systematics (Mayr 1982: 237 and 245). Yet, he was too good a naturalist to be swayed by the promises of cladistics, or phylogenetic systematics, that a simple comparison and digitization of characters will lead to the discovery of the true evolutionary history of organisms (see Mayr and Bock 2002). He recognized the necessity and usefulness of classifications as a method to create order within biology and to maintain an information retrieval system, but he also knew that structures and molecules have functional attributes, through which they interact with the environment. Hence, he was keenly aware that the evolutionary history of taxa is described not only by their branching into clades, but also by their phyletic evolution as shown especially by their adaptations to their environments.

Interestingly enough, the evolutionary process of populational change up to the level of species is not necessarily being opposed by anti-evolutionary critics of the Theory of Evolution. The direct or indirect influence of Mayr's work may well have had a hand in this acceptance. In addition, overwhelming evidence for 'microevolution' has accumulated through the appearance of pesticide-resistance in bacteria, insects, and rats; the appearance of new breeds of domesticated animals; and the existence of distinct local populations. What anti-evolutionists oppose in particular, however, is the history of macroevolutionary change [i.e. historical-narrative explanations of Bock (2004)] as reconstructed by biologists through the application of the Theory of Evolution [i.e. nomological-deductive explanations of Bock (2004)]. Anti-evolutionists may feel justified in their claims because evolutionary history is often recounted in the popular press, and also in some textbooks, in a narrative style that, on the surface, can sound surprisingly similar to revealed tales of origins (e.g. dinosaurs appeared first in the Triassic and disappeared due to the impact of a giant comet, but not before giving rise to birds). Such distillations of highly complex historical processes can be deciphered by knowledgeable biologists, but even biology students (or physicists) may not always be sufficiently equipped to plumb the actual scientific depths of such statements. If evolutionary biologists are "just theorizing" (as it may appear to non-biologists) that because of a drying of the climate during the Miocene, the ancestors of human beings left their forested habitat for the savannahs, then, indeed, the story of Adam and Eve may sound just as plausible to scientifically naïve people as an explanation on how human beings came to be. However, as scientists know, the fundamental difference between the two accounts is that the former's heuristic value lies in its implicit sub-hypotheses that can be further explored and tested through independent studies of, for example, the paleoclimate of the Miocene through analysis of pollen, floral and animal fossils and the comparative biomechanics of relevant primate and hominid fossils. In contrast, the story of Adam and Eve may have poetic and evocative powers, but lacks corollaries that are amenable to independent testing by scientific objective means.

As anti-evolutionists have not succeeded in claiming that religious stories of origin are just as scientific as evolutionary biology, they have recently developed a strategy to question the current explanation for the evolution of complex organs and organisms. The problem of how to account for the phenomenon of macroevolutionary change had already worried Darwin (1859) when he tackled the "Difficulties of the Theory" and discussed the evolution of organs of extreme perfection and complication, which he explained as the result of a cumulative series of minute evolutionary changes. Mayr (1954), in contrast, approached the problem from an angle of population thinking and proposed a mechanism of genetic revolution in small isolated populations in which a new genotype can evolve rapidly and is not swamped by the genotypes of a large population. This idea was later elaborated into the Theory of Punctuated Equilibria by Eldredge and Gould (1972; see also Mayr 1997). Both Darwin's and Mayr's explanations, however, eschewed the question of how organisms that are already highly integrated and complex can be changed further without breaking down like a watch with which a child has tinkered. In other words, I believe that the salient question in macroevolutionary biology is not just how complex organs and organisms could have evolved from simpler ones, but how organisms that have reached a high degree of integration and complexity can continue to change at all.

In a highly integrated and complex organism (or machine), all elements mesh harmoniously with one another, so that it is difficult to conceive how any one element could be modified without disrupting the entire system. Hence, there is a real need to develop a new appreciation for variability within the complex systems of individual organisms in analogy to the population thinking of Mayr's at the species level. By establishing for a complex organ or organism which elements do not vary and which ones do, it will be possible to discriminate between variations that would presumably disrupt the functioning of an organism and, hence, would have been eliminated by natural selection, and those that would not disrupt the functioning of an organism and, hence, could persist and possibly change the morphology of an organism, respectively. Such insights would be a crucial step towards understanding the possibilities for and constraints against evolutionary changes of complex organisms. However, despite the discussions and open questions that currently concern the conceptualization of the detailed processes that are involved in macroevolutionary change, the overarching Theory of Evolution is not a matter of debate among biologists: A constant generation of genetic variations that are subjected to the test of viability of the organisms bearing them by the selective regime of their environment. A complete explanation of the phenomenon of macroevolution may 'simply' require another major effort in disentangling yet another level of biocomplexity.

Another step towards a better understanding of the process of large-scale morphological changes of highly integrated complex organisms will eventually be achieved by an *a priori* conceptualization of organisms as complex entities. The prevalent reductionistic approach, however, tends to simplify complex organisms and organs *a priori* in the expectation that once selected elements of a system are known, the whole organism could be reconstructed from them, and other elements could be integrated later. But this integrative phase of a study is rarely performed, probably because the organism may not have been understood as an entity in the first place. Organs and organisms need to be analysed while keeping their inherent complexity in mind (see, for example, Homberger 1986, 1999; Duncker 1991), and models of their essential aspects need to be created *a posteriori* (Homberger 1988). The different results of the *a priori* and *a posteriori* approaches to model building are analogous to the different answers one can expect from a young person versus an older person when asked to name what are the most important things in life. I believe that an explicit and detailed explanation of the mechanisms of structural and functional changes of complex organs and organisms will eventually remove vestiges of anti-evolutionism just as the explicit and detailed explanation of the mechanisms of microevolutionary changes has been accepted universally.

Yet another reason for any lingering anti-evolutionism stems from a deep-seated feeling among some religious people that the Theory of Evolution has moral implications that are contrary to their own sensibilities (see also Homberger 2002). They have been quite explicit in what they fear: If the presence of man is due just to an accident, then there is no deeper meaning to our lives; if human beings are nothing but (or 98%) hairless apes, then human beings may feel free to behave like apes, without the restraints arising from laws and moral guidelines; and if antagonistic competition is THE driving force of life and humanity (as social Darwinists, but neither Darwin nor Mayr, have claimed), then there is no place for love, cooperation, friendship, and self-sacrifice, and no one would want to live in such a world. Because our world is often portrayed as being driven by ruthless competition, lack of empathy, unapologetic and boundless greed, thoughtless aggression, and disregard for human life, it is easy to see that the Theory of Evolution, as portrayed by catch phrases, can easily be made into a scapegoat for the ills of our world. Like Marxism, feminism, anti-colonialism, and atheism, the idea that the human species differs from animals only by degrees and is subject to impersonal natural forces like all other living organisms questions the validity of existing power structures and their readings of dominant philosophies and religions. And because biologists are generally unwilling, or unable, to address such anxieties, both the anti-evolutionists and the biologists have been talking past each other. The issue at hand is not whether the idea of an all powerful God can co-exist with the reality that the Theory of Evolution has been corroborated over and over again as the best explanation for the phenomenon of living organisms on this earth. Biologists who make it an issue miss the point. The issue at hand is whether our scientific insights and understandings are not only providing heuristically meaningful explanations for natural phenomena, but can also inform and nourish our human, mental and spiritual needs.

Mayr's work provides a way out of this dilemma. Mayr knew that complex issues require a certain quantity of words to be analysed, discussed and explained. At the same time, he possessed a remarkable capacity for clarifying complex issues with a great economy of words as is beautifully exemplified by his diagram of Darwin's theory (Mayr 1997: 190). This linguistic precision and accuracy may have been aided by an innate talent, but it certainly was honed and polished by his training in the German university-preparatory Gymnasium system that required the mastery of three languages besides the mother tongue (i.e. classical Greek, Latin, and one contemporary foreign language, which was French in Mayr's time) through an intellectual process based on an intimate knowledge of grammar and vocabulary. In addition, Mayr learned English as an adult in his mid-twenties. As every native speaker of German realizes when he has to learn English well enough to write about abstract ideas, complexity and subtlety are expressed in English by a precise use of vocabulary in contrast to German, in which they are expressed by creative arrangements of words and phrases that indicate the precise meaning of words through context. The wrestling with such different approaches to communication must have sensitized Mayr to the hidden meanings and concepts of words (see also Homberger 1998). The theory of evolution as an extremely complex explanation of the phenomenon of living organisms, which cannot be condensed into catch phrases without distorting it or, worse, making it sound like any other story about the origin of life.

Mayr's exposure to philosophy in the German Gymnasium and university system and his lifelong interest in the philosophy of science may have also allowed him to deal with the moral implications of the theory of evolution. His understanding of the Theory of Evolution does not lead to a pure materialism, but opens windows unto an ethical landscape ["evolutionary humanism" of Mayr (1997)] that may lead us towards a path of spirituality (Mayr himself does not use this word) that is in tune with the needs and exigencies of our troubled, overcrowded, destructive, normative and standardizing culture. For example, he shows that diversity, whether biological or cultural, is not only 'good' in terms of modern ideas of nature conservation and democratic principles, but, more importantly, is necessary for a population or a culture to be able to adapt to the continuously changing environmental and cultural conditions. A close reading of his work also disproves the more than silly *dictum* "survival of the fittest" and questions the overriding power of antagonistic competition as shaper of the world by showing that the idea of a single 'best' individual in natural populations is biologically nonsensical. And a deeper understanding of the Theory of Evolution also helps to replace our need for showing that we human beings are better than and separate from animals so that we can deny them feelings and, therefore, can justify our use of them as we please without moral qualms and our destruction of their habitats to promote our own, often only short-term economic progress. (Such arguments are uncomfortably reminiscent of arguments that have been used in the past to deny humanity to certain groups of people). But if, as the Theory of Evolution instructs, all living species are connected to us and are, if not our brethren and sisters, at least our cousins and friends, then we can start to implement a more enlightened and less destructive approach to the world's resources and all living creatures. These ideas are not Mayr's alone, but Mayr's (1997) description of the evolution of altruism and ethics in human beings, for example, is an excellent illustration of his clear style of argumentation and is a convincing explanation for why ethical and moral behaviour is not restricted to religious people.

But if Mayr provides an approach to evolution that actually opens the door for a dialogue among all human beings of any personal conviction, how come that he is almost unknown among the broader public? Mayr dealt with complex issues, he was an intellectual and a 'teacher' in the best sense of the word, and he had no desire to be popular. But perhaps more importantly, his work does not address the one major frontier of evolutionary biology: Macroevolution. Furthermore, his work is not directly applicable to the evolution of dinosaurs and not easily adaptable to a television program.

Anti-evolutionism and its latest avatar, Intelligent Design, find their inspiration in Christian revelations and have been, to this day, most virulent in the United States. But as it will spread to other continents, it will encounter other religions. Will science classes then really include a balanced curriculum of all existing stories of human origin? Or is it not rather that science has been so successful and so widely integrated into all cultures because it tries to understand reality independently from particular religious beliefs and, therefore, can bring all people to the same universal table of scientific enquiry and understanding? The heuristic value of the Theory of Evolution is its real and persisting value. Mayr may have left to us the complete solution of the mechanism of macroevolutionary changes in complex organisms, but he has provided us with a firm foundation for the exploration of this question and many other questions in biology by clarifying the dizzying complexity and multiplexity of populations, subspecies, and species.

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