

## Medicine Needs Evolution

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THE CITATION OF “EVOLUTION IN ACTION” AS *SCIENCE*’S 2005 BREAKTHROUGH OF THE YEAR (1) confirms that evolution is the vibrant foundation for all biology (2). Its contributions to understanding infectious disease (3) and genetics (4, 5) are widely recognized, but its full potential for use in medicine has yet to be realized (6-10). Some insights have immediate clinical applications, but most are fundamental, as is the case in other basic sciences. Simply put, training in evolutionary thinking can help both biomedical researchers and clinicians ask useful questions that they might not otherwise pose.

Although anatomy, physiology, biochemistry, and embryology are recognized as basic sciences for medicine, evolutionary biology is not (11). Future clinicians are generally not taught evolutionary explanations for why our bodies are vulnerable to certain kinds of failure. The narrowness of the birth canal, the existence of wisdom teeth, and the persistence of genes that cause bipolar disease and senescence all have their origins in our evolutionary history (7). In a whole array of clinical and basic science challenges, evolutionary biology is turning out to be crucial (8). For example, the evolution of antibiotic resistance is widely recognized, but few appreciate how competition among bacteria has shaped chemical weapons and resistance factors in an arms race that has been going on for hundreds of millions of years



(12-16). The incorrect idea that selection reliably shapes a happy coexistence of hosts and pathogens persists, despite evidence for the evolution of increased virulence when disease transmission occurs through vectors such as insects, needles, or clinicians’ hands (3, 17). There is growing recognition that cough, fever, and diarrhea are useful responses shaped by natural selection (18), but knowing when is it safe to block them will require studies grounded in an understanding of how selection shaped the systems that regulate such defenses and the compromises that had to be struck (19).

Evolution is also the origin of apparent anatomical anomalies such as the vulnerabilities of the lower back. Biochemistry courses cover bilirubin metabolism, but an evolutionary explanation for why bilirubin is synthesized at all is new: It is an efficient free-radical scavenger (20). Pharmacology emphasizes individual variation in genes encoding cytochrome P450s, but

their evolutionary origins in processing dietary toxins are just being fully appreciated (21, 22). In physiology, fetal nutritional stress appears to flip an evolved switch that sets the body into a state that protects against starvation (23). When these individuals encounter modern diets, they respond with the deadly metabolic syndrome of obesity, hypertension, and diabetes (24-26).

The triumphs of molecular biology call attention to evolutionary factors responsible for certain genetic diseases. The textbook example is sickle-cell disease, whose carriers are resistant to malaria (27, 28). Similar protection against infection has been hypothesized for other disorders (29). Which aspects of the modern environment are pathogenic? We need to find out. Increases in breast cancer have been attributed to hormone exposure in modern women, who have four times as many menstrual cycles as women in cultures without birth control (30, 31). Other studies suggest that nighttime exposure to light increases the risk of breast cancer by inhibiting the normal nighttime surge of melatonin, which may decrease tumor growth (32). Evolution has also provided some explanations for conditions such as infertility. The process that eliminates 99.99% of oocytes may have evolved to protect against common genetic defects. And some recurrent spontaneous miscarriages may arise from a system evolved to protect against investing in offspring with combinations of specific genes that predispose to early death from infection (33).

These and other examples make a strong case for recognizing evolution as a basic science for medicine. What actions would bring the full power of evolutionary biology to bear on human disease? We suggest three. First, include questions about evolution in medical licensing examinations; this will motivate curriculum committees to incorporate relevant basic science education (34). Second, ensure evolutionary expertise in agencies that fund biomedical research. Third, incorporate evolution into every relevant high school, undergraduate, and graduate course. These three changes will help clinicians and biomedical researchers understand that both the human body and its pathogens are not perfectly designed machines but evolving biological systems shaped by selection under the constraints of tradeoffs that produce specific compromises and vulnerabilities. Powerful insights from evolutionary biology generate new questions whose answers will help improve human health.

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