The aim of medical education is simple: to teach future physicians how the body works and the ways in which it fails so they can offer high-quality diagnosis and treatment. This is why medicine is based on biology. But so far, medicine has made full use of only one half of biology—the proximate half explaining how the body works. The other half, evolutionary biology, is only now being recognized as an essential basic science for medicine. Instead of explaining how the body works, evolutionary medicine (or Darwinian medicine) asks why the body is constructed the way it is and why it works the way it does. Incorporating evolutionary theories into the practice of medicine can offer a fuller explanation of disease and a better understanding of the body.

If you ask why polar bears are white or why we get fever in response to infection, you are asking evolutionary questions. To answer these questions, you have to find out why natural selection kept the DNA sequences that give a species its particular characteristics. Only in the past few years have researchers begun to ask these questions in regard to disease. Instead of only asking why certain people get a disease and others do not, researchers well-versed in evolutionary theory are questioning why each disease exists, and they are trying to find out why all of us have bodies that are vulnerable to so many diseases.

At first it might seem that natural selection can only explain what works, not what fails. After all, individuals who have genes causing them to die young tend to have fewer children than other people. Those deleterious genes become less common over the generations. You would think this process would make the body better and better. In fact, it has. So, why do we get sick at all? Is it just because natural selection is a random process that can’t make anything absolutely perfect? This is one reason, but only one.

It turns out that the human body is a bundle of evolutionary constraints and compromises. Sometimes it seems miraculously perfect; at other times its design seems absurdly poor. As a medical student, you experience this contrast as you make the transition between your second and third years. If the basic sciences are taught well, you emerge from your second year with a profound respect and even a sense of awe for the body’s apparent perfection. The wonders of cellular differentiation during development, the counter-current multiplication in Henle’s loop, and the systems that regulate glucose, oxygen pressure, temperature and salt bal-

Dr. Randolph M. Nesse, co-author of *Why We Get Sick: The New Science of Darwinian Medicine*, encourages us to look at the human body and disease through the lens of evolutionary medicine.
ance are nothing short of astounding. In biochemistry—if you can get your head above memorizing the details—you see a landscape with incredibly complex components all working together to regulate the thousands of processes making life possible. Hardly anything is more inspiring than learning how the body works.

Then you get to the clinic. Suddenly, the body doesn’t seem perfect at all. Many patients have high blood pressure and many more have diabetes. Atherosclerosis runs rampant. Cancer cells divide out of control. Even childbirth seems a product of poor planning. Who would route the birth passage through a small circle of bone, when an opening on the abdomen would be easier and more efficient? Why are there wisdom teeth? Why do we have an appendix? Is it as if Mercedes engineers were in charge of the body’s initial design, but then turned it over to an amateur bicycle mechanic with a sick sense of humor. How can some parts of the body be so perfect, while others are so crudely flawed?

The answer is simple: An engineer didn’t shape the body; natural selection did.

It’s all about reproduction

We think the body is designed for health, but it isn’t. Natural selection maximizes reproduction, not survival or health. Any gene or trait that tends to increase the chances of an individual’s reproductive success (think: number of grandchildren) will become more common even if it harms health. This is the essence of natural selection and the foundation for evolutionary theory.

Consider a hypothetical gene that gives us benefits when we’re young by strengthening our bones, yet causes us to die early because it calcifies our coronary arteries. Since such a gene would offer an advantage while we’re young and reproducing, it would be selected for and become more common. For physicians practicing in the 21st century, this example has sobering implications. If your genetic consultant recommends eliminating a universal gene that causes aging, you would want to pause and ask the evolutionary question: Why is this gene present? Is it really just an abnormality or does it also offer benefits?

A different environment

Another evolutionary reason for disease is the mismatch between the environment in which we evolved and the modern world in which we live. For most of our history, we lived as hunter-gatherers, walking 10 to 20 miles daily in search of food. Since fat and sugar were in short supply, natural selection gave us cravings for fatty, high-calorie foods and tendencies to avoid exertion. When calories were hard to come by, such cravings and behaviors were advantageous. Now, however, we can have hamburgers with fries nearly any time. The systems that evolved to regulate our food intake were shaped for an entirely different environment. This is why 50 percent of Americans are overweight and 25 percent are now obese.

The transition from foraging to buying groceries was particularly rapid for the Pima Indians in the American Southwest. Dr. James Neel, a pioneer in human genetics, studied the Pima Indians in the second half of the last century. He found that they were mostly healthy just a hundred years ago when they lived in a hunter-gatherer society, but now the majority are obese and more than 40 percent have diabetes. The sudden transition to a modern environment has devastated their health.

The arms race with pathogens

Another reason our bodies are susceptible to disease is that bacteria and viruses evolve much more quickly than our defenses are able to. Infection is a powerful selection force, and it shapes powerful defenses, but we can never get perfect protection against such a changeable foe.

Bacteriologists used to think that, over time, pathogens evolved to reduced virulence, since the pathogen was seemingly dependent on the continued survival of its host. If the host dies, the pathogen dies, so reduced virulence would benefit the pathogen—or so one would think. Proponents of this view did not fully understand that natural selection does not select for genes that increase cooperation in nature or even survival per se. Instead, as emphasized by biologist Paul Ewald, it selects for genes that increase reproductive fitness. In other words, a pathogen is shaped to whatever level of virulence that maximizes its own reproduction.

If a cold virus makes you so sick that you have to stay home and away from others, your sneezes will never transmit the virus to other people. The reproductive capability of the virus is effectively ended. Natural selection therefore selects for cold viruses that do not incapacitate us. On the other hand, if pathogen transmission does not depend on host mobility, no such selection for reduced virulence would take place. For example, because cholera is transmitted through the diarrhea it produces, a victim sick in bed can still spread the virus if the diarrhea can get into the water supply. In this case, the pathogen’s transmission depends not on the host’s mobility, but on the volume of diarrhea produced. So strains making people sicker spread faster. The same is true for E. coli infections in a hospital. They are usually transmitted by the hands of medical staff, a circumstance leading to the evolution of increased virulence.

To get a better idea of this, consider some of Ewald’s research into the cholera epidemic that has been unfolding over the past decade in South America. In areas where public sanitation is good, the cholera bacterium can spread only if people are up and around, so natural selection should lower cholera’s virulence. However, where water systems are contaminated by sewage, strains that produce more diarrhea should reproduce faster. Sure enough, Ewald has discovered that in areas without modern sanitation, selection is making cholera more dangerous, as measured by the amount of toxin produced by the bacteria.

Defenses

We are by no means helpless against infection; natural selection has armed us with all kinds of defenses. We have skin that steadily sheds its outer layer, high concentrations of stomach acid to kill bacteria, a powerful immune system and a subjective sense of disgust in response to bodily substances likely to be contaminated. We also have defenses that expel pathogens: cough from the trachea, rhinorrhea from the nose, vomiting from the upper gastrointestinal tract and diarrhea from the lower bowel. Infection also arouses fever; contrary to some older notions, it is not a
problem but part of a solution. Bacteria and viruses can’t grow as well when our body temperature rises. These defenses stay latent until the body detects a situation in which they are likely to be useful, and then they are expressed. Nearly every one of them is aversive. We dislike vomiting. We want to stop coughing, and we want to rid ourselves of fever and malaise.

Much of medical practice consists of blocking these defenses. But if they are so useful, how can we block them without harming our patients? The answer is found in how natural selection shapes the mechanisms regulating a defense’s expression. When is it worthwhile to release the vomiting reflex? Should it be whenever the body detects any possible toxin in the gut? No, this would cause constant vomiting. Should the system wait until it detects many grams of a toxin? No, this could result in death. A defense mechanism’s optimal setting is determined by the “smoke detector principle.” Smoke detectors are set to a hair trigger that sets off many false alarms. But we tolerate these minor annoyances in order to be warned of every real fire; the alarm saves our lives. The systems regulating pain, anxiety, vomiting, cough and fever are set according to the same principle. These responses aren’t costly, so they’re expressed whenever they might be helpful, including many cases in which they’re not really necessary. This is why physicians can use drugs to block some of these false alarms.

But if the symptom is truly a defense—not a false alarm—perhaps we don’t want to stop it. For example, a physician who excessively reduces pneumonia patient’s cough—a bodily defense used to expel the pathogen—is increasing the patient’s chances of dying.

Nor are all symptoms defenses. Many are manipulations of our molecular machinery by invading organisms trying to increase their chances of reproduction. For example, cholera makes a toxin that disrupts the ability of the lower bowel to absorb water, thus creating diarrhea that spreads the infection. A physician who does not replace the fluid lost by a cholera patient—a manipulation by the bacteria—may well consign him to death. Therefore, if a symptom represents a manipulation of our machinery by a pathogen, the physician should go after it.

From these examples, you can see how a physician armed with an understanding of evolutionary medicine can approach the treatment of patients with a new viewpoint and ask: Is the symptom a defense or a direct manifestation of a disease?

It would be unthinkable to receive a Ph.D. in biology without learning evolutionary theory. Yet, even though medicine is based on biology, medical schools teach almost no evolutionary biology. When evolutionary biology is finally recognized as a basic medical science, physicians will ask new questions based on these theories, and the answers to those questions may well solve some of medicine’s most enduring problems. Meanwhile, physicians who do understand evolutionary theories will at least be able to give patients better explanations for why they get sick—perhaps patients’ most frequent question.

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Resources
For more information about evolutionary medicine:
Evolution in Health and Disease, Stephen Stearns, editor, Oxford University Press.
Evolution of Infectious Disease, by P.W. Ewald, Oxford University Press.
Evolutionary Medicine, by W.R. Trewathan et al., Oxford University Press.
The “Evolution” project by WGBH/NOVA Science Unit and Clear Blue Sky Productions:
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