Culture and Medicine

How is Darwinian medicine useful?

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INTRODUCTION

Evolution by natural selection has been biology's organizing principle for more than a century, but only in the last few decades has it been applied to the social sciences and medicine. Its application to medicine, known as evolutionary or Darwinian medicine, uses an evolutionary perspective to understand why the body is not better designed and why, therefore, diseases exist at all.[1-3] This article outlines some basic principles of Darwinian medicine, summarizes the usefulness of evolutionary principles for medicine, and provides some examples from key literature sources.

For example, traditional clinical medicine looks at the problem of obesity in terms of individual differences that explain why one person becomes obese and another does not. These factors may be due to genes, early environment, or current lifestyle. Now that one half of Americans are overweight, however, it is time to answer the evolutionary question: why are our bodies designed so that most of us eat too much and exercise too little?

EVOLUTIONARY EXPLANATIONS FOR OBESITY

An initial answer is simple. In the environment in which we evolved, natural selection shaped appetite regulation mechanisms to ensure that we survived periods of famine. In those ancient times, eating required walking for hours each day to get food, a caloric cost that made it impossible for most people to accumulate much surplus as fat.[4] Exposure to intermittent periods of food shortage sets off a system that prepares for a coming famine by increasing appetite and basal weight above the starting point. Dieting activates the same system, so weight can rebound to above what it was when the diet began. When young people try to lose weight by using willpower to drastically limit their food intake, their regulation mechanisms react with a response that is adaptive: they often gorge themselves. These episodes of uncontrolled eating can make the dieter even more fearful of becoming obese, so still further efforts of will arouse the mechanism more strongly, setting in cycle the positive feedback spiral we see in anorexia and bulimia.

As for our food preferences, one would think we would be designed to eat what is good for us. The system would work fine if we lived on the African savanna. In the natural environment, fat, salt, and sugar are in such short supply that when they are encountered, the useful response is to consume them. Fat provides twice as many calories per gram as carbohydrates. Sugar is often associated with ripe fruits, and seeking it out was usually beneficial. Now that we can choose our foods, we prefer what was in short supply on the African savanna.

We also choose our levels of exercise to minimize caloric expenditure—a wise strategy in the Paleolithic era when wasting calories could bring death. This tendency to be sedentary, in combination with our preferences for large amounts of high-calorie, high-fat food, has resulted in an epidemic of atherosclerotic disease. Natural selection will eventually fix such design problems, but it will take hundreds or thousands of generations to do so.

EVOLUTION AND ANXIETY DISORDERS

Anxiety disorders offer another example of Darwinian medicine in action.[5] We know anxiety can be useful, but why do so many people experience so much of it, so often, when it seems worse than useless?

In ancient times, anxiety was necessary for humans to flee from a predator. This "fight and flight" mechanism is built into our nervous systems. It is triggered at the wrong time in people with panic disorder. If a panther were approaching, however, it would be valuable. Agoraphobia, the fear of open spaces and the tendency to stay close to home or to flee at the least hint of danger, is considered a phobia in modern societies, but is the optimal response if predator attacks have been frequent.[5]

Summary points

- Darwinian medicine asks why the body is not better designed
- Obesity and its complications arise because our body is not designed for a modern environment
- Natural selection adjusts virulence levels to whatever is optimal for the pathogen
- Defenses, such as fever, cough, and anxiety, are painful but are useful in evolutionary terms
- An evolutionary view of medicine sees the body as a product of natural selection, extraordinary in many ways but also flawed for evolutionary reasons

SYMPTOMS AS EVOLUTIONARY DEFENSES

An evolutionary approach can fundamentally change how we think about the body and disease.[6] Instead of seeing disease as a defect in a previously perfect machine, Darwinian medicine allows us to see the body as a product of natural selection, full of trade-offs and vulnerabilities that all too often lead to disease. Physicians are not mechanics repairing broken parts; they are guides who understand the trade-offs that give rise to disease and come up with strategies that will oppose the effects of other organisms, compensate for what the body cannot repair, and relieve suffering when possible.

For example, pain, nausea, cough, fever, vomiting, diarrhea, fatigue, and anxiety are common medical problems. Much of medical practice focuses on relieving suffering by prescribing medications that block these responses. A different view is that these responses are not problems themselves but represent the body's attempt to remedy a problem. If defenses are so useful, and natural selection is potent, then prescribing medicines may be unsafe. If fever, cough, and diarrhea are useful defenses, blocking them might make people sicker. Treating *Shigella*-induced diarrhea, for example, substantially increases complications.[7] The excessive suppression of cough can cause death. Extreme circumstances require a balanced approach, however; for example, blocking fever can prevent febrile seizures, and stopping vomiting can prevent dehydration.

Why has natural selection shaped the body so these defenses are expressed so readily and intensely? The answer is the same as the explanation for why we tolerate smoke detectors that sound a false alarm every time the toast burns. You could design a detector that went off only when there was extensive smoke, but the disadvantage would be the absence of the alarm in response to some fires. Defenses such as pain and fever are inexpensive compared with the dangers they avert, so natural selection has shaped regulation mechanisms that express them whenever they might be useful. As a result, it is usually possible to block them safely.[8] As for that most hackneyed bit of medical advice, "take aspirin and drink plenty of fluids," perhaps studies will soon be conducted to determine if this speeds or slows recovery from everyday infections.

CLINICAL APPLICATIONS OF DARWINIAN MEDICINE

Understanding common illnesses

Most medical research asks why one person gets a disease and another does not. Darwinian medicine suggests asking an additional and different line of questioning: why are we all vulnerable to certain diseases?[6,9] Why are we all likely to get hemorrhoids, impacted wisdom teeth, and pneumonia? Why will so many of us experience myocardial infarction, cancer, or rheumatoid arthritis?

Most people think that the answer is simply that natural selection cannot make the body any better than it has. After all, it is a random process with no direction or coordination. In fact, the body is not better designed for specific evolutionary reasons.

One important reason is that natural selection does not shape organisms for health or longevity but for maximizing reproduction, even at the expense of a shortened life span. When there is a conflict—for instance, when a gene improves bone healing in youth but also causes arterial calcification—that gene will be selected for even though it leads to fatal outcomes in later life. Where there is a conflict between reproductive success and health, reproduction always wins out.[10]

Answering questions about etiology

Another way in which evolutionary biology is useful in medicine is to answer classic questions about the etiology of disease. For instance, evolutionary medicine can provide specific approaches to the problem of antibiotic resistance. The story of pathogen virulence provides the best example. It seems that it would not be in their interests for pathogens to kill the host that supports them. Given sufficient time, virulent pathogens should gradually evolve into a benign mutualism with their hosts. The steady decrease in the virulence of syphilis over the past 5 centuries has often been interpreted in this way, probably correctly. Pathogens that cause severe and often fatal disease, such as cholera, are thought to be still in the process of adapting to their host.

This notion is incorrect, however. In work summarized by Ewald, it became clear that natural selection shapes whatever level of virulence maximizes the replication of bacteria and viruses.[11,12] Often, as with rhinovirus, the pathogen spreads more rapidly if the host is up and around. Other pathogens, however, such as *Plasmodium* species are spread by vectors. Mosquitoes are more effective vectors when the host is prostrate. Genetic variants that replicate more quickly are selected for and increase in prevalence.

This fact has immediate practical implications for infection control. The hands of medical staff are a vector, so it is not surprising that nosocomial *Escherichia coli* strains tend to become increasingly virulent with the duration of circulation in a medical setting. Furthermore, these organisms are exposed to antibiotics, so they are likely to become resistant to treatment. A neonatal nursery is well designed for breeding "superbugs." The difficulty of exterminating these bugs may warrant cutting off their evolutionary pathway occasionally by moving nurseries at intervals to a completely different sterile room with fresh supplies and no transfer of infants from the previous nursery. The prospect of interrupting the further evolution of nosocomial pathogens might justify the considerable expense.

Identifying improvements for public health

Where water supplies are contaminated by sewage, selection acts to increase virulence. Public sanitation changes the selection forces, giving the advantage to less virulent organisms. Where new sources of clean well water have been provided, especially in India, virulent pathogens such as *Shigella dysenteriae* and classic *Vibrio cholerae* have been replaced by less virulent *Shigella flexneri* and the El Tor subtype of *V. cholerae.*[13]

CONCLUSION

Everyone uses metaphors to understand the world. The dominant metaphor for the body has been a machine. Disease has been viewed as a defect arising in an otherwise perfect device. An evolutionary view offers a richer and more nuanced view of the body as a product of natural selection: extraordinary in many ways, but also flawed in many ways, for good evolutionary reasons. Furthermore, it reveals that the body has no master plan and there is no such thing as "the" human genome. Humans have genes that make phenotypes that effectively make new copies of themselves. We care less about the fate of our genes, however, and more about the health and welfare of individuals.

Darwinian medicine will most powerfully advance our goal of helping individuals by inspiring research that yields solid new findings to guide health care practice. Even at this early stage, however, Darwinian medicine can help clinicians answer old questions, pose new questions, and provide a more natural view of disease.

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