Chapter 13: Essay

The Genetics of Muscle Fitness

There are three types of muscles: smooth, cardiac, and skeletal. Smooth muscles help move food and certain fluids through your body. Cardiac muscles pump blood through your heart. Skeletal muscles attach to your bones allowing you to run; dance; lift; turn; and, in general, move through your environment. Physical fitness involves resilience in all muscle types. For this essay, however, our focus will be on the more physically apparent skeletal muscles, which can account for up to 40 percent of your total mass.

Figure A
Why does exercise make us stronger? The answer has to do with the activation of our DNA.

Muscle tissue is energetically expensive to maintain. Even at rest, your skeletal muscles consume about 25 percent of your energy. Thus, it is not in your body's interest to have more muscle mass than it needs. For this reason, our muscles adapt. If we exercise a lot, our muscles become bigger and stronger. Conversely, muscles wither away without exercise—a fully immobilized muscle loses about one-third of its mass within weeks. From personal experience, we know that muscles are responsive to use. But how is this accomplished? Why do your muscles get stronger when you exercise and get weaker when you don't? The answer is that exercise involves more than your muscles. When you exercise, you are also exercising your DNA.

As discussed in Chapter 13, DNA holds the information for how to build proteins. This includes all the proteins associated with building your muscles, of which there are two kinds. First, there are the proteins that actually become part of your muscles. Second, there are "regulator" proteins that serve to direct the building of your muscles. These regulator proteins act like managers at a construction site, in that they determine when building should speed up or slow down. If DNA gets a signal that more muscle mass is needed, it creates more regulator proteins that are designed to speed up muscle protein synthesis where needed. Likewise, if DNA gets a signal that muscle production needs to slow down, it creates more regulator proteins designed to inhibit muscle protein synthesis. So, DNA is the master controller. It actually produces hundreds of different muscle regulator proteins, and each one has a specific purpose.

Regulator proteins also play a role in how much energy is made available to muscles. An example is the GLUT regulator protein, which sits on the surface of muscle tissue. Its function is to pull glucose, an energy-rich sugar molecule, from the bloodstream and into the muscle. You always have some GLUT proteins to enable muscle movement. As you exercise, however, you stimulate your DNA to create more of these proteins. A single decent exercise routine causes a significant increase in GLUT proteins. What this means is that your muscles can now pull glucose more efficiently out of your bloodstream, even while you are at rest. If you were to eat a potato, your blood sugar level would not rise as much as it would have if you hadn't exercised.

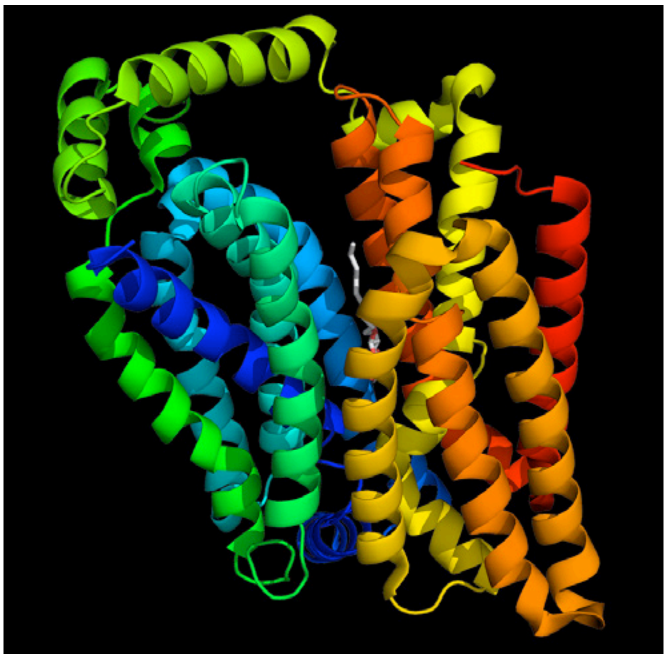

Figure B
The structure of a GLUT protein shown here in a "ribbon" model, which helps to highlight its many alpha helices.

GLUT proteins generally degrade after 24 hours. With continued exercise, your DNA replenishes the GLUT proteins, and eventually an optimal number of them are retained. If you were to stop exercising, their positive effects would naturally fade away within a day or two. With no exercise over many years, your DNA becomes inefficient at producing GLUT proteins. The result is often unusually high blood sugar levels and a disease called type 2 diabetes.

Most of the energy used by your cells comes from a high-energy molecule known as *ATP* (see Section 13.6). ATP is produced using energy that comes from the oxidation of food. This occurs in small cellular organelles called *mitochondria*. How efficient mitochondria are at producing ATP is a function of the number of regulator proteins they contain. So, what produces these regulator proteins? Your DNA. What happens when you exercise? You stimulate your DNA to make more of these regulator proteins within mitochondria; hence, more ATP becomes available to your cells, including your muscle cells. It takes about a week for the number of these regulator proteins to double. After about a month of regular exercise, you reach a plateau. In everyday language you would say you are "in shape." What you really mean, however, is that your DNA is in shape, because it is now producing an optimal number of regulatory proteins that produce an optimal amount of ATP so that you are fit to perform physically demanding tasks, such as running for a long time. So, what happens when you don't exercise? ATP production is minimized, and the energy of food is directed to the production of energy-storage tissues such as fat. Why does the body produce fat? So that the precious energy it contains might be available for labor-intensive activities at a later date, when food may not be so abundant.

Our bodies are smart, but the rules of the game have recently changed. For many thousands of years, we relied on our DNA-mediated performance mechanisms to allow us to hunt, gather, and grow food; to build shelters; and to walk or jog long distances. These are all labor-intensive activities. It has only been within the last 100 years that such activities have become mechanized. We walk much less because we have cars. We gather much less of our own food because we have grocery stores. The Centers for Disease Control and Prevention have noted a growing increase in obesity that coincides with the rise in sedentary lifestyles. While obesity can be traced to the intake of food as well as the

< Figure C

For type 2 diabetes, the body has difficulty removing sugar from the blood stream, which means the diabetic needs to monitor their sugar levels regularly.

quality of that food, another half of the equation often gets neglected, which is exercise. Our bodies are designed to be physically active. Harm comes to us when we neglect this calling.

Muscle Doping

Our knowledge of DNA is recent, but we are well on our way to learning how to control and tinker with its mechanisms. The IGF-I regulator protein speeds up muscle- building processes. To build bigger and stronger muscle tissue, why don't we simply inject IGF-I into our muscles? This doesn't work because the IGF-I dissipates within hours. What is needed is a continual source of IGF-I. Toward this end, researchers have successfully implanted the DNA that codes for IGF-I within the muscles of rats, which, without exercise, develop up to 30 percent more muscle mass. With exercise, the genetically "doped" muscles of these "super rats" become nearly twice as strong.

The insertion of DNA into a person to allow the creation of certain proteins is known as *gene therapy*. The idea of gene therapy was dreamed up soon after the discovery of the structure of DNA in the 1950s. Although the idea is straightforward, it is only within the past decade, after years of intensive basic research, that success is starting to be realized. Muscle- enhancement gene therapy is poised to become one of the first gene therapies to be made available to the general population. Such therapy holds great promise for the treatment of muscular dystrophy, as well as for the treatment of muscle weakness that comes with age. But it also raises a number of interesting questions. How safe is the procedure? Might such therapy lead to cancer? Are the inherent risks worth the benefits? Will we be more or less likely to exercise after having our muscles doped with muscle-strengthening DNA? Should athletes be allowed to genetically dope their muscles for better performance? How about military personnel? The ethical issues surrounding genetic enhancement are many and complex.

Figure D
Usain Bolt set the world record for the 200 meter dash in 2009 as well as the 100 meter dash in the same year.

CONCEPT **CHECK**
What do 7 days without exercise make?

CHECK YOUR ANSWER Seven days without exercise makes one weak. Got it? Good. Now get to it.

Think and Discuss

1. Should athletes be allowed to genetically dope their muscles for better performance? If so, should there be two sets of Olympics, one for the doped and another for the non-doped? Many Olympians may already benefit from natural mutations that enhance their performance. Why not level the playing field by making such enhancements available to all athletes?

2. A new line of drugs known as nootropics are being developed to help us learn. Consider the social implications. What parallels might there be between sports- enhancing drugs and these intelligence-enhancing drugs? If these drugs are found to be safe, should they be available only by prescription? If they are found to be unsafe, should they be banned or should they be con- trolled, like alcohol and tobacco?

3. Gene therapy is not passed along to offspring because it does not affect the reproductive cells. For an individual, however, a single dose may last a lifetime. So, what restrictions should be placed on muscle-enhancement gene doping? Should it be allowed only for the treatment of medical conditions? Should it be made available only to people over the age of 21?

4. Might gene therapy ever become as routine as vaccinations? By when? What might be some social or political hurdles to the acceptance of such therapies?

5. How much money would you be willing to pay for effective muscle- enhancement gene therapy?

6. Muscle-enhancement gene therapy also interferes with fat deposition. How might the food industry respond to a population of consumers who could eat all they wanted and still remain trim without exercising much?

Author Responses to Think and Discuss

1. Two sets of Olympics would be interesting, but consider how the International Olympic Committee now staggers the summer and winter games by two years so as to improve media ratings. Perhaps many genetically dope athletes would find themselves in the company of professional wrestlers. Should the playing field be leveled? Tough question. What is it that we value most in an athlete?

2. Safe or unsafe, the social implications of a line of drugs that help us learn better are huge. These could be of benefit to people suffering from learning disabilities, such as ADHD, or diseases of the brain, such as Alzheimer's. They could become a drug of choice for students competing to get top grades, or for older adults trying to keep up with younger and quicker minds. Will nootropics help us to become more creative? Will they help us grow wise? Stay tuned for recent developments.

3. Much research should be performed to assess the risks and benefits of muscle enhancement gene-doping. Only then can society determine what to do next.

4. As per the previous question, much research will be needed to assess the risks and benefits of muscle enhancement gene-doping. Only then can society determine what to do next.

5. If proven safe and effective, the price for muscle-enhancement gene therapy could be initially quite high, which would restrict the benefits to the wealthy. That wouldn't help to alleviate the growing disparity between the rich and the poor.

6. Favorably.