Muscle Evolution Is a Major Problem for Neo-Darwinism: A Review

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Abstract

Muscle has a structure that is irreducibly complex and shows no evidence of progressive evolution when a comparison is made between different animals. The skeletal muscles in a bee are little different in anatomy and function than those in a human. Muscle in all life-forms is so similar that it requires training and a good microscope to tell the difference. It appears reasonable to conclude that organisms in each kind were endowed with their own well-designed muscle tissues.

Introduction

Muscles are critical for animal life. They are used not only to move gross structures, but also to adjust many small living units such as the eyeball. Humans require muscles to lift a book, blink an eye, take a step, curl a finger, throw a ball, or even just to inhale a breath. Muscle tissue is considered so important by researchers that one scientist who discovered how muscle cells function said he worked in this area because it "came closest to the essence of life" (Vogel, 2001, p. 11).

Neo-Darwinists predict that muscle in animals like worms, insects, and mammals should show an ascending sequence of evolutionary "advances." This is not what researchers have found. The study of comparative anatomy has revealed that muscles across the entire animal kingdom differ little in basic design and function, whether we study a bee or a human. Yet they accomplish many diverse tasks, such as humans walking, flies flying, rattlesnakes rattling, and squids shooting black liquids in order to hide in the water. Muscle design in fleas, elephants, and humans is almost identical; it is so close that it requires both a microscope and a trained eye to discern the difference (see Vogel, 2001, pp. ix, 1). Muscle tissue sold as a food is called *meat*. Meat inspectors must employ biochemical testing with antibodies in order to detect efforts to swindle customers by trying to substitute cheaper meat, such as horse meat for cow meat.

Types of Muscle

The four basic types of both vertebrate and invertebrate muscle are: (1) fast skeletal, (2) slow skeletal, (3) cardiac, and (4) smooth (OOta and Saitou, 1999). They can be differentiated by location: *skeletal* muscles are attached primarily to bone and occasionally to the skin, *cardiac* muscle forms the walls of the heart, and *smooth* muscle forms the walls of hollow structures such as the blood vessels, the stomach, and the intestine. The microscopic appearance of skeletal and cardiac muscle is striated, not smooth (Saladin, 1998). Cardiac muscle has a built-in pacemaker to achieve autorhythmicity, and smooth muscle often also utilizes autorhythmicity to function. Skeletal muscle is consciously controlled, while cardiac and smooth muscles are largely controlled by neurotransmitters and hormones. Vogel (2001) concludes that muscle contains the same design in all life:

> The same device powers a microorganism, thirty-thousandths of a millimeter long, that powers a whale, thirty meters (one hundred feet) or a million times longer. Muscles do differ among themselves—red muscle, white muscle, fibrillar muscle, catch

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> muscle—but we mustn't lose sight of the underlying commonality of cross-striated skeletal muscle. In mechanism of action, in speed of action, in force production, in power output, muscles differ less among themselves than do the electric motors that power our home appliances (p. 95).

Furthermore, the "architecture of a given muscle is extremely consistent among individuals of the same species and the same basic architectural principles exist throughout the animal kingdom" (Lieber and Friden, 2000, p. 1647). The function of all muscle can be summarized as follows: nerve stimulation causes it to draw its ends together, or to try to, such as to hold something in one place. Even muscle mitochondria are very similar in invertebrates and vertebrates (Henwood, 1992). This similarity conflicts with the evolutionary concept of neo-Darwinism.

The Anatomy and Physiology of Muscle

About half of a human's weight is muscle mass. The five basic functions of the body's muscle system are: (1) to cause body motion (such as walking), (2) to stabilize the body position (such as standing or sitting), (3) to cause movement of substances within the body (the heart pumps blood, and the smooth muscle contracts to aide movement of food through the intestinal tract), (4) to regulate organ volume (such as moving the contents through a hollow organ), and (5) to function in thermogenesis (muscle contractions generate as much as 85 percent of all body heat). Called an "electrical engine," muscle is a "remarkable engine: soft, wet, and contractible" (Vogel, 2001, p. 18).

All muscle tissue has five characteristics: (1) irritability, the property to respond to stimuli by producing electrical signals called *action potentials* that lead to movement; (2) conductivity, the ability of a cell to propagate action potentials; (3) contractility, the ability of muscles to shorten and thicken to cause movement and do work; (4) extensibility, the ability of the muscle to extend without damaging the tissue; and (5) elasticity, the trait allowing a muscle to return to its original shape after contraction or extension (Seeley et al., 2003).

Skeletal muscles are well supplied with blood vessels for the high level of nutrients they require in order to perform their necessary functions. Blood is needed in order to convey nutrients the muscle cells require to make ATP, to repair the muscle cells, and also to remove the waste products produced by the many chemical reactions that occur in muscle. Interrelations like these between muscles and the blood system illustrate how the body itself, vertebrate or invertebrate, is irreducibly complex. Each of many parts of the body must be present and functional for the body to operate efficiently. This type of "irreducible complex" system is strong evidence of design.

Nervous Control

Muscle control is achieved by electrical-chemical signals. A nerve signal travels along a path separated by a neuromuscular junction called a *synapse*, a term that means "connection." The synapse functions as a switch and usually is located in a region containing a small gap (the synaptic cleft) that separates the two nerve cells. To bridge this gap requires a neurotransmitter to travel from the nerve to the muscle. At the neuromuscular junction, the synapse between the neuron and muscle fibers (the distal part of the axon terminal) expands into a synaptic end bulb that contains many membrane-enclosed sacs called *synaptic vesicles* (see Figure 1). The evolutionary origin of muscle control by such electrochemical signals remains unexplained after decades of research.

The synaptic vesicles contain the neurotransmitter molecules. The neuromuscular junction uses acetylcholine as a neurotransmitter. The other side of the synaptic cleft is the motor end plate, which contains about 30 to 40 million acetylcholine receptors. When a nerve impulse reaches the synaptic end bulb, it triggers the liberation of acetylcholine, which diffuses into the synaptic cleft and binds to the receptor, causing an inrush of sodium ions. The ions change the resting membrane potential, triggering a muscle action potential that travels along the muscle cell plasma membrane, initiating muscle contraction (Seeley et al., 2003). The complexity, and also the simplicity, of this sequence remain unexplained by neo-Darwinism.

Motor nerves deliver the stimulus that causes the muscle cell fibers to contract. The neuron, plus the set of about 150 muscle fibers it stimulates, is called a *motor unit*. All the muscles in a motor unit contract and relax together.

In order to function, muscles require many support structures—the origin of which cannot be explained by neo-Darwinism. Muscle alone is "a semisolid gel" that requires heavy sheets of connective tissue to function (Vogel, 2001, p. 11). Examples include faciae (from Latin *fascia*, meaning "bandage"), which are sheets of fibrous connective tissue that surround muscles. The first are superficial faciae, which are immediately below the skin and function to provide mechanical protection against trauma and support for nerves and blood vessels that enter and exit the muscles. The second type, deep faciae, is a dense irregular connective tissue that surrounds muscles, separating them into functional groups and allowing their free movement and support for nerves, blood vessels, and lymphatic vessels (Saladin, 1998).

Tendons (from *tendere*, "to stretch out") are cords of dense connective tissue that attach muscle to the bone periosteum. The aponeurosis (*apo*, "from," and *neuron*, "a tendon") is a fibrous sheetlike membrane resembling

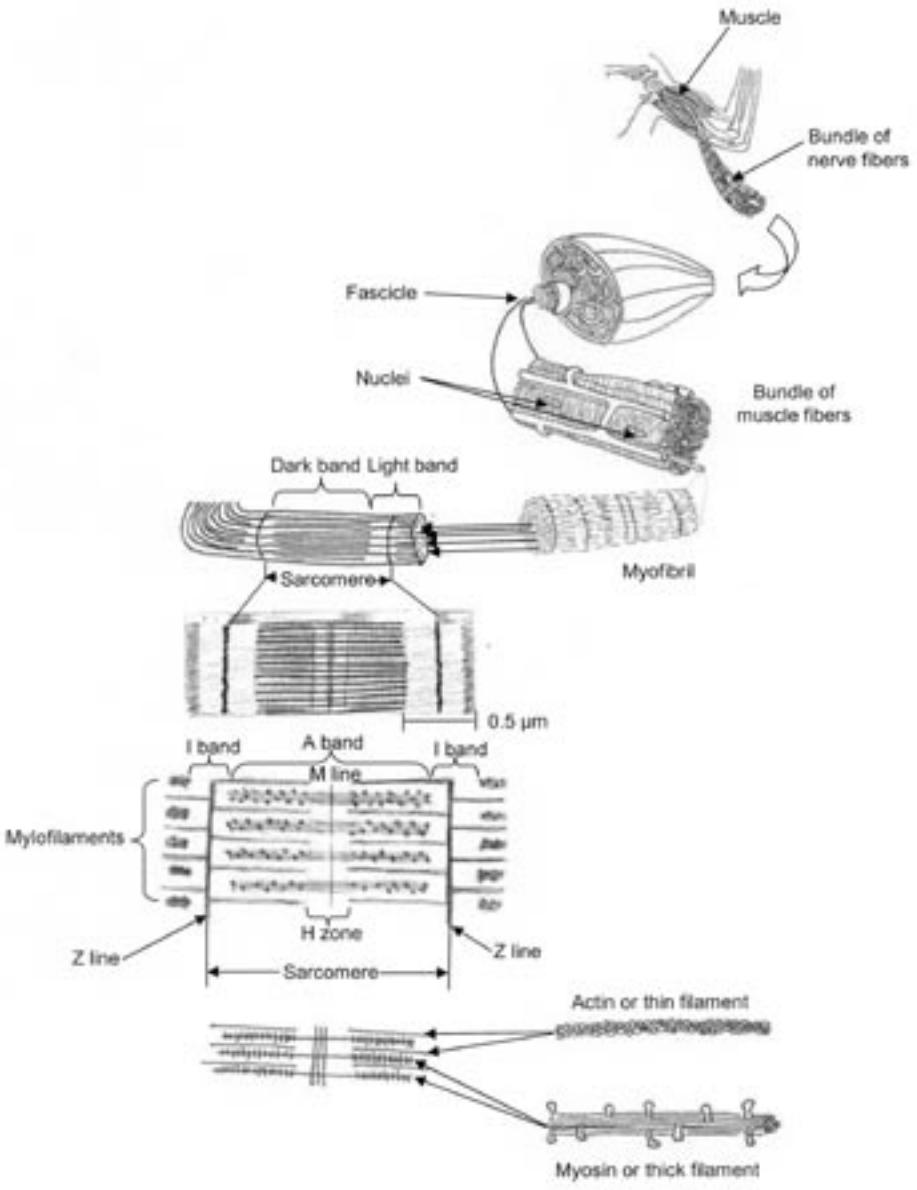

Figure 1. The neuromuscular system showing the gross and microanatomy of a muscle. The muscle in the arm consists of a bundle of nerve and muscle fibers. Each muscle fiber consists of a single cell with several nuclei. The muscle fibers inside the muscle cell are called *myofibrils* and are bundled in sets connected and separated by various structures such as fascicles. A bundle of muscle fibers consist of many myofibrils, each of which contains mylofilaments and actin. Actin strands are also called *thin filaments*. The thin and thick components interdigitate, forming light bands and dark bands when viewed under a microscope. When enlarged farther, various distinct regions can be seen, including I and A bands, M lines, the H zone, and the Z line. The bottom of the illustration shows the mechanism of muscle contraction powered by ATP. Essentially, the actin and myosin move together similar to sliding one's fingers together to shorten the space between one's hands, a process called *interdigitation*. (Figure adapted from Saladin, 1998, and Seeley et al., 2003).

a flattened tendon. It is a sheet of connective tissue that extends as a *broad flat layer over the muscle*, attaching it to the covering of a bone muscle or skin.

Skeletal Muscle Structure

A microscopic examination of the skeletal muscle structure reveals hundreds or thousands of long cells called *muscle fibers* or *myofibers* that lie parallel to each other. They range from 10 to 100 micrometers in diameter. The plasma membrane of the muscle cell is the *sarcolemma* (*sarco* means "flesh," and *lemma* means "sheath"). It surrounds the muscle fiber cytoplasm called the *sarcoplasm*. During embryonic development a single muscle arises from the fusion of many smaller cells called *myoblasts*. For this reason each muscle fiber has many nuclei located at the cell's periphery, conveniently out of the way of the contractile elements. The mitochondria are oxidative organelles that lie in rows throughout the muscle fibers, a functional arrangement that allows muscle proteins to use the large amounts of adenosine triphosphate (ATP) required for contraction (see Figure 1 for a diagram of the basic parts and operation of muscle). Critically important are the myofibrils (the skeletal muscle's contractile elements) that contain both thin and thick filaments (Seeley et al., 2003). These cellular anatomical details support the origin of muscle cells by design, not gradual evolution by a step-wise method. One reason is that muscle will not function unless, and until, all of the parts shown in the diagram are present. Without the thin filament, the thick filaments, the nucleus, the myofibril, and many other parts, it will not function.

Muscle contraction is caused by an interdigitating sliding filament system. Although the exact mechanism involved in muscle contraction remains elusive, it is known that it is very complex, requiring scores of different proteins—at least

six types including titan are involved in the sliding mechanism alone (see Vogel, 2001, p. 20). The myosin heads pull on the thin filaments, causing them to slide towards the H zone located in the center of the thick filaments. When maximally contracted, the thin filaments overlap, producing muscle shortening.

An increase in calcium ion concentration in the sarcoplasm initiates the filament movement, and, conversely, a decrease in calcium stops movement. Active transport pumps move calcium from the sarcoplasm into the sarcoplasmic reticulum organelle. Calcium released from the sarcoplasmic reticulum combines with troponin, causing troponin to change shape, which moves the troponin-tropomyosin complex away from the myosin-binding sites on actin.

The Z-discs are endplates that connect adjacent muscle cells. Vogel (2001) called them "complicated structures made up of at least four other kinds of protein" (p. 20). The high-energy yielding phosphate compound ATP provides most of the energy required for muscle contraction. When a muscle is relaxed, ATP attaches to specific ATP binding sites on the myosin cross bridges located on the myosin projections. On the myosin head there exists a section that acts as ATPase, an enzyme that uses hydrolysis to split ATP into ADP plus a phosphate group.

A result is the transfer of energy from ATP to the myosin head, energizing the myosin cross bridges. When the calcium level rises to a certain level in the sarcoplasm, the tropomyosin moves away from its blocking position, causing the activated myosin heads to spontaneously bind to the myosin binding sites on actin. This produces the power contraction stroke, causing the myosin heads to swivel toward the center of the sarcomere, similar to the way boat oars move during rowing. As the myosin heads swivel, they release ADP to be recycled. The interrelation of parts required in this system is another example of irreducible complexity that requires design.

Muscle fibers relax after contraction because acetylcholine is rapidly broken down by acetylcholinesterase. This ends the generation of the muscle action potential and causes the calcium release channels in the sarcoplasmic reticulum membrane to close. In addition, a second set of calcium-active transport pumps moves calcium from the sarcoplasm back into the sarcoplasmic reticulum, where calsequestrin, a calcium-binding protein, removes the calcium out of solution, allowing even more calcium to be sequestered within the sarcoplasmic reticulum. This mechanism is so effective that the calcium concentration is 10,000 times lower in the sarcoplasm of a relaxed muscle fiber than it is inside of the sarcoplasmic reticulum.

The Architecture of Muscle

Muscle is highly organized not only at the microscopic level but also at the gross morphological level. Skeletal muscle is part of a complex bone, ligament, and tendon system that must function as a unit according to biomechanical laws (Lieber and Friden, 2000). Even though muscle and associated tissues are very similar across the animal world, the entire system must be designed to function effectively as a unit in each specific organism type. Understanding muscle architecture requires a knowledge of structural properties that dominate the function of whole muscle sets (Lieber and Friden, 2000). Similarities and differences that exist are primarily a result of biomechanics, design constraints, and design requirements and not common ancestry.

The Types of Muscle

Only three basic types of tissue contractile systems exist in animals. The first involves actin and other fibers inside of cells that cause cell movement, such as in protozoans. The next type is the relatively unspecialized contractile cells in sponges and in certain more complex animals (Dorit, Walker and Barnes, 1991, p. 214). The last type is the muscle system covered in this paper. These three systems are very different, and no evidence of evolution from one to the other exists. Furthermore, no empirical evidence of muscle evolution exists, although many studies have been completed attempting to show homology between different muscle forms (Itina, 1979; Johnston et al., 2004; Laing et al., 1995; Meedel et al., 1997; Fukuzawa et al., 2001; McGuigan et al., 2004; Ferry-Graham and Lauder, 2001; Clayton et al., 1988; and Gibson, 1986). While some variation exists, all known muscle types are as complex as the system discussed in this paper.

Built-in flexibility for certain traits, such as muscle fiber size, is required for an animal to adapt to specific environmental changes. Johnston et al. (2004) found evidence that although regulation of myotube production in fish is under high selection pressure, an optimal fiber size exists that varies directly with body size. This optimal size is the result of a trade-off between mechanical and other constraints on fiber diameter and the energy costs necessary to maintain the required ion gradient level. This finding helps us to understand how life can adapt to various environments, but only within certain limits. Contrary to the claims of some, this is not evidence of macroevolution, but evidence for a designed system that allows for adaptation to limited environmental changes.

Some researchers have tried to use muscle differences that exist for clearly functional reasons to speculate about evolutionary histories. Hoh (2002), in a study of comparative vertebrate muscles, included speculation about possible muscle evolution. He openly admitted, however, that this is only suggestive and is not based on direct evidence. Mastropaola (2001) found no evidence

of muscle evolution in a mathematical analysis of the maximum-power stimulus theory of muscle development but rather found evidence for design. He concluded that the "human muscle was meticulously nanoengineered by a designer" and that the "reasonable conclusion from science is that muscle and all other living tissues were designed" (Mastropaola, 2001, p. 219).

The Fossil Record of Muscle

Although soft tissue does not preserve well in the fossil record, muscle tissue is preserved effectively in several situations, such as in amber samples of insects. Amber has been shown to aid in preserving details down to the cell ultrastructure, including the structure of cell organelles (Henwood, 1992). Soft tissues, "especially flight muscle," are frequently preserved in Dominican, amber-entombed animals (Henwood, 1992). Dominican amber is usually assigned from the upper Eocene to the lowermost Miocene.

Muscle fibers also have been found in insects trapped in Baltic amber that are believed to have "formed about 40 million" years ago (Poinar and Hess, 1982, p. 1241). Insects have "a complex musculature, possessing approximately twice the number of muscles as do mammals" (Grimaldi, et al., 1994, p. 7). Evaluation techniques of tissue entombed in amber are still imperfect, but continue to improve. The clearly defined muscle bands and other structures studied so far "resembled present-day tissues that had been dehydrated with ethylene glycol," the solution used to preserve the tissue (Poinar and Hess, 1982, p. 1242).

Muscle tissue also can be effectively preserved in animals caught in tar pits or frozen in ice. Some evidence now exists of muscle preservation in dinosaurs. Soft tissues have been identified in dinosaur bones that reportedly are nearly 70 million years old (Wilford, 2005; Nance, 2005). A nine-inch-long baby Theropod found in a limestone bed near Naples, Italy contained muscle tissue in the pectoral area (Dal Sasso and Signore, 1998).

In a process not yet fully understood, "gill and muscle tissue and even the cell nuclei of ... fish which are 120 million years old, can be preserved by phosphate minerals" (Palmer, 1994, p. 17). Not only were blocks of muscle tissue found, but individual muscle fibers were identified as well. In one study the most published finding was of "soft, fresh-looking tissue inside a T. Rex femur" including blood vessels constructed out of smooth muscle (Yeoman, 2006; Fields, 2006). The research team concluded that the "vessels and contents are similar in all respects to blood vessels recovered from extant ostrich bone" (Schweitzer, et al., 2005, p. 1952).

So far, all of the ancient muscle structures that have been evaluated are close to identical to modern muscle. Henwood (1992) concluded that the small differences between modern and fossil insect flight muscle that have been examined are "best explained by taphonomic circumstances" (p. 206)—in other words, the differences are caused by changes due to the preservation process, such as water loss, and not to evolution of muscle tissue. Bundles of "muscle fibers in their original origins and insertions"—and even Z- and M-lines and T-tubules with a "startling lifelike fidelity—have been identified in many samples of Dominican amber" (Grimaldi, et al., 1994, pp. 1, 7–8, 10). The samples examined so far indicate that the oldest known muscle samples compared with modern samples show that muscle anatomy and physiology have not changed.

Summary

All muscle types in all animals are very similar in structure and function, and all are irreducibly complex machines that must function as part of a complex, well-designed interconnected system as described in this paper. Muscle is part of a very complex system that could have functioned only if every basic component were present from day one. It had to be a fully functional system from the beginning, and without functional muscle very few animals, from insects to mammals, could exist. This fact contrasts markedly to the Darwinian prediction that primitive life used primitive muscle, and more advanced life-forms used more evolved and more complex muscle. No simple muscles exist; rather all muscle in all life, from simple to complex, contains the same components and the same basic design as reviewed in this paper. There is not any evidence for the evolution of muscle in the fossil record. Muscle has always been muscle since its origin in each living kind.

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References

CRSQ: Creation Research Society Quarterly.

Bergman, J. 1999. ATP: the perfect energy currency for the cell. *CRSQ* 36:2–9.

Clayton, L., F.C. Reinach, G.M. Chumbley, and A.R. MacLeod. 1988. Organization of the hTMnm gene. Implications for the evolution of muscle and non-muscle tropomyosins. *Journal of Molecular Biology* 201:507–515.

Dal Sasso, C., and M. Signore. 1998. Exceptional soft-tissue preservation in a Theropod dinosaur from Italy. *Nature* 392:387.

Dorit, R.L., W.F. Walker Jr., and R.D. Barnes. 1991. *Zoology*. Thomson, New York, NY.

Ferry-Graham, L.A., and G.V. Lauder. 2001.

Aquatic prey capture in ray-finned fishes: a century of progress and new directions. *Journal of Morphology* 248:99–119.

Fields, H. 2006. Dinosaur shocker. *Smithsonian* 37(2): 50–55.

Fukuzawa, A., J. Shimamura, S. Takemori, N. Kanzawa, M. Yamaguchi, P. Sun, K. Maruyama, and S. Kimura. 2001. Invertebrate connectin spans as much as 3.5 μm in the giant sarcomeres of crayfish claw muscle. *The EMBO Journal* 20:4826–4835.

Gibson, G.A.P. 1986. Evidence for monophyly and relationships of chalcidoidea mymaridae and mymarommatidae hymenoptera terebrantes. *Canadian Entomologist* 118:205–240.

Grimaldi, D., E. Bonwich, M. Delannoy, and S. Doberstein. 1994. Electron microscopic studies of mummified tissues in amber fossils. *American Museum Novitiates* 3097:1–31.

Henwood, A. 1992. Exceptional preservation of dipteran flight muscle and the taphonomy of insects in amber. *Palaios—The Society for Sedimentary Geology* 7:203–212.

Hoh, J.F.Y. 2002. Review: "Superfast" of masticatory myosin and the evolution of jaw-closing muscles of vertebrates. *The Journal of Experimental Biology* 205:2203–2210.

Itina, N.A. 1979. Evolution of muscle function: comparison of striated muscle characteristics in tunicates and vertebrates. *Zhurnal Evoliutsionnoi Biokhimii I Fiziologii* 15:401–413.

Johnston, I.A., M. Abercromby, V.L.A. Viera, R.J. Sigursteindottir, B.K. Kristjansson, D. Sibthorpe, and S. Skulason. 2004. Rapid evolution of muscle fibre number in post-glacial populations of arctic charr salvelinus alpinus. *The Journal of Experimental Biology* 207:4343–4360.

Laing, N.G., S.D. Wilton, P.A. Akkari, S.Dorosz, K.Boundy, C. Kneebone, P. Blumbergs, S. White, H. Watkins, D. Love, and E. Haan. 1995. A mutation in the α tropomyosin gene *TPM3* associated with autosomal dominant nemaline myopathy. *Nature Genetics* 9:75–79.

Lieber, R.L., and J. Friden. 2000. Functional and clinical significance of skeletal muscle architecture. *Muscle and Nerve* 84:1647–1666.

Marieb, E. 2005. *Anatomy and Physiology*. Pearson, San Francisco, CA.

Mastropaolo, J. 2001. The maximum-power stimulus theory for muscle. *CRSQ* 37:213–220.

McGuigan, K., P.C. Phillips, and J.H. Postlethwait. 2004. Evolution of sarcomeric myosin heavy chain genes: evidence from fish. *Molecular Biology and Evolution* 21:1042–1056.

Meedel, T.H., S.C. Farmer, and J.J. Lee. 1997. The single MyoD family gene of *Cona intestinalis* encodes two differentially expressed proteins: implications for the evolution of chordate muscle gene regulation. *Development* 124:1711–1721.

Nance, A. 2005. Perhaps a step toward dinosaur DNA. *New York Times National,* Friday, March 25, p. A15.

OOta, S., and N. Saitou. 1999. Phylogenetic relationship of muscle tissues deduced from superimposition of gene trees. *Molecular Biology and Evolution* 16:856–867.

Palmer, D. 1994. How busy bacteria turn into stone. *New Scientist* 1917:17.

Poinar, G.O., Jr., and R. Hess. 1982. Ultrastructure of 40 million year old insect tissue. *Science* 215:1241–1242.

Saladin, K. 1998. *Anatomy and Physiology*. McGraw and Hill, New York, NY.

Schweitzer, M.H., J.L. Wittmeyer, J.R. Horner, and J.K. Toporski. 2005. Soft-tissue vessels and cellular preservation in *Tyrannosaurus rex*. *Science* 307:1952–1954.

Seeley, R., T. Stephens, and P. Tate. 2003. *Anatomy and Physiology*. McGraw Hill, New York, NY.

Stokstad, E. 2005. *Tyrannosaurus rex* soft tissue raises tantalizing prospects. *Science* 307:1852.

Vogel, S. 2001. *A Natural History of Muscle*. Norton, New York, NY.

Wilford, J.N. 2005. Dinosaur find takes scientists beyond bones. *New York Times National,* Friday, March 25, pp. A1, A15.

Yeoman, B. 2006. Schweitzer's dangerous discovery. *Discovery* 27:37–41 and 77.