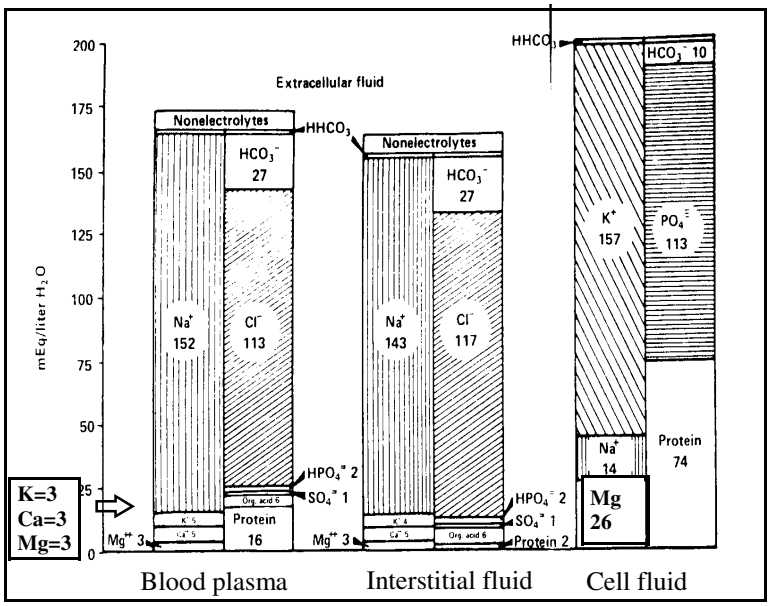
How Magnesium Allows Muscle Relaxation

by Tessa Jupp RN from "Human Physiology" by L Sherwood , West Publ Co, Minneapolis USA 1993

A recent addition to our Polio Library is the above book with actual diagrams and text showing the action of magnesium in allowing muscle to relax.

But before we look at that, let's look at the diagram to the right, from "The Nervous System" by W Ganong, Lange Med Publ, California, 1977, which illustrates very well, the electrolyte (ie mineral) composition of body fluids. As you can see, blood and fluid around the cells, have high levels of sodium (Na) and chloride (Cl) (ie normal saline or salt) and low levels of magnesium (Mg), calcium (Ca) and potassium (K). However, inside the cell itself, this ratio is reversed, with high potassium, magnesium, phosphate and cell protein.



Most of the calcium in the body is found in bone. In the actual muscle cell, calcium is kept separate in a special box called the reticulum, as it has the job of jumping out to make the muscle contract, when it gets the message from the nerve to do so.

So the outside fluids are our transport system, like our roads and cars and the cell is like our home where we bring the grocery shopping, turning it into useful food when we cook it to make a meal.

Part of the "cooking process" is turning the plant (carbohydrate) foods into glucose to produce energy and turning animal foods (proteins and fats) into fatty acids to provide even more energy than glucose.

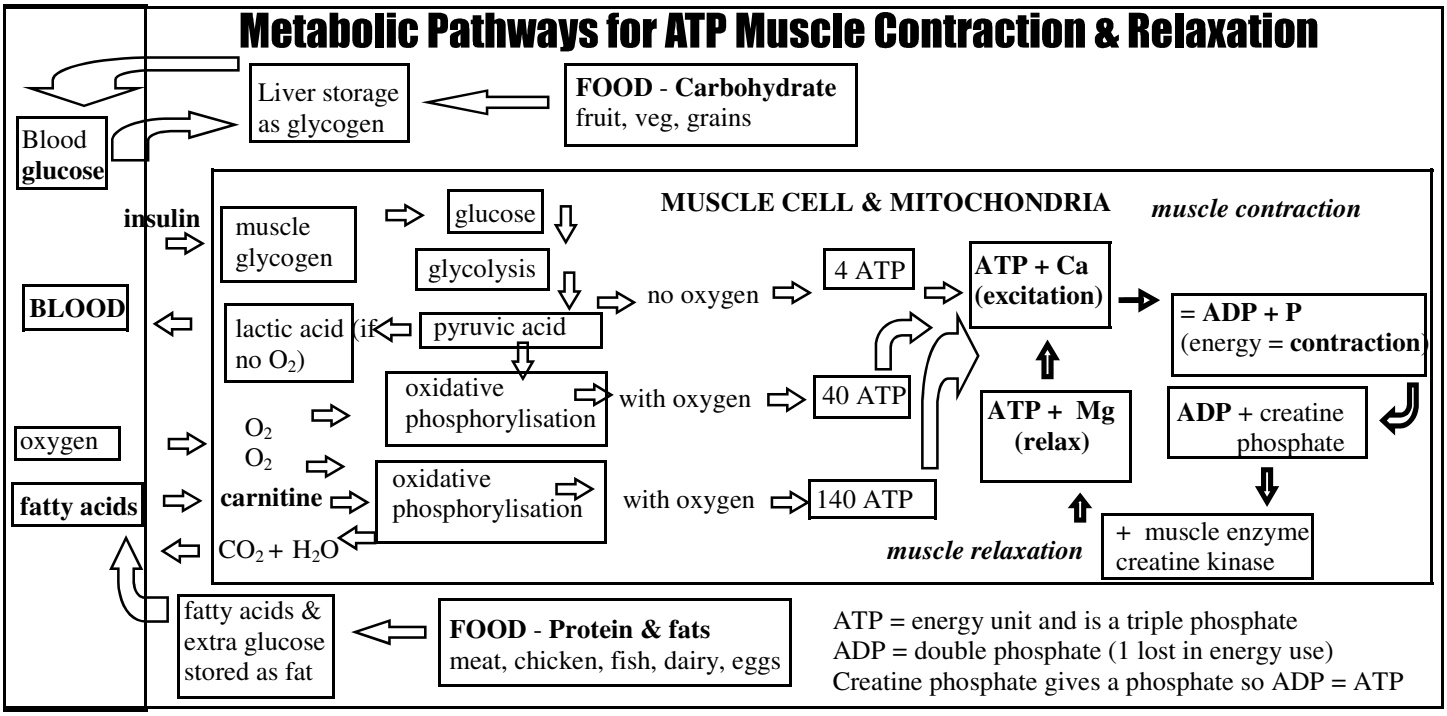
The diagram below from "Human Physiology" shows how the food eventually ends up as ATP, which are the energy units of the body. ATP is the energy needed for muscle to contract and relax.

Glucose, transported in with the assistance of insulin produces only 4 ATP without oxygen but 40 ATP with oxygen. This is the fuel of choice of Type 2 or quick action muscle.

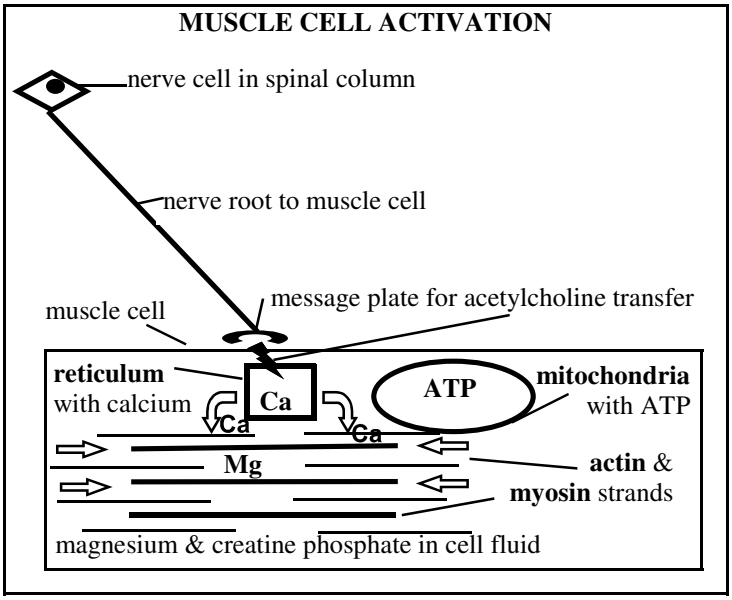
Fatty acids, from protein foods or fat storage breakdown in the body (ie our reserves) give a lot more - 140 ATP. Carnitine is required to transport this fuel into the mitochondria of the muscle cell. This is the fuel of choice for Type 1 or endurance muscle, such as back, neck, legs, arms.

If fatty acids and carnitine are not available, glucose can be used but as we see, less energy results, so a lot more glucose is required to get the same amount of energy. To process this, more insulin is required, eventually putting a strain on the insulin system which may lead to diabetes.

Metabolic Pathways for ATP Muscle Contraction & Relaxation



Muscle contraction is quite complicated when we get down to the smallest parts but the diagram drawn below attempts to show how the nerve in the spinal column sends the message from the brain or a reflex action, to activate a muscle contraction.



In Polio the damage occurs in the anterior horn cells (movement nerves) in the spinal column. Problems may be present now due to further deterioration occurring in the nerve cell or compression along the nerve root. B6 is used by the body in nerve repair.

Or there may be a problem at the neuro-transmitter stage - the nerve endplate at the muscle. If the neuro-transmission is poor, there may be too little acetyl-choline available. Taking some extra choline may help in acetyl-choline production.

If the problem is occurring in the muscle cell, there may be a breakdown in any of the ingredients used within the muscle cell as mentioned in the metabolic pathways.
USA polio research shows that there is a dominance of type 1 muscle in polio survivors. These muscles need carnitine and fatty acid fuels for best function. If energy is low and fatigue is a problem, diet and carnitine levels need to be addressed.

If anaemia is present (ie iron or B12 is low) then oxygenation can be down, again necessary for ATP production. Shortness of breath from low oxygen can also result.

So we get to muscle contraction and relaxation. In WA, many of our foods are grown on limestone which is high in calcium. We actually get plenty of calcium here and excess calcium results in tight, contracted muscles. It is magnesium and other minerals that are low in WA soils. So if a muscle is short of magnesium, it will have problems relaxing. Cramps and muscle pain result and energy levels will drop.
Magnesium is essential for many enzyme reactions involved in energy metabolism.

Now we can look at the smallest parts of muscle movement. In diagram (A) from the book below, we can see the actin molecule, which is like a string of beads with the tropomyosin strand woven around it. On this strand is a pimple of troponin. It is this pimple that the calcium is attracted to when it jumps out of the reticulum box. Calcium attachment moves the strand slightly, exposing or unlocking, the hidden contact point, allowing the myosin crossbridge head which was cocked and waiting, to make contact. (2)

When this happens, the ADP and separated phosphate are fired from the myosin producing energy that moves the head and attached actin strand ie muscle contraction. (3) The ADP leaving frees the ATP site for another ATP to attach. In skeletal muscle, magnesium must also be attached to the ATP. When a new ATP + Mg attaches this breaks the connection with the actin (4) and the muscle relaxes. The myosin ATPase enzyme cocks the head again by using the magnesium to split the ATP to ADP + P (1), so that it sits relaxed but waiting, ready for when the next bit of calcium comes along to unblock the site and fire the ADP energy off again. Successive firing by calcium pulls the muscle tighter until ATP &/or magnesium run out. Without sufficient magnesium, the actin and myosin stay locked together. Cramps and muscle pain result.

Continuous firing stops when the nerve's acetyl-choline release stops. The reticulum shuts the "out" gates and opens the "in" gates, calling back released calcium, ready for the next signal.