BLOODWORMS AND LEGO BLOCKS

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Bloodworms are the larvae of the midge fly. Lego blocks are little plastic thngs that kids use to build stuff. What do bloodworms and Legos have in common? Well… nothing - but stay with me for a moment.

A midge fly is about the same size as, and looks sort of like, a mosquito. But, they do not bite. If you see a mosquito-like thing with fluffy antenna and no proboscis, it is probably a midge fly. There are many species of midge fly. They occur from the tropics to the tundra and their larvae can be found in almost every shallow aquatic environment. Some species live in salty waters. New species are still being described by man. Almost all species have similar life cycles. You may hear them called to chironomids, referring to the family name Chironomidae. In many aquatic habitats, chironomid larvae are the most common animal which is large enough to be seen with the naked eye.

Midge flies lay eggs in water. The eggs mass is a small, clear jelly-like glob that looks much like aquatic snail eggs. The eggs hatch into small worm-like larvae. If you look at the larvae with a magnifying glass or microscope, it appears less worm-like and has a segmented outer shell like other insect larvae. Most midge larvae have a bright red color. The red coloration is from a hemoglobin-like substance which allows them to live in water with very little oxygen. Thus, midge larvae are red for much the same reason that our blood is red – because it contains iron and carries oxygen. It is then not too surprising that midge larvae are called blood worms.

The larvae are opportunistic omnivores. They eat a variety of things including single cell algae, bits of decaying organic matter and other small plants and animals. They seem to be able to find something to eat just about anywhere.

The midge larva sheds its shell (exoskeleton) as it grows. After four molts, it becomes a pupa. The pupa stage usually lasts only a few days. The pupa molts and metamorphoses to an adult which crawls out of the water and flies away. The adults do not eat. Their function is to reproduce, fly around porch lights and die a few weeks later.

Bloodworms spend most of their time attached to the bottom or other solid surface. Older and larger bloodworms may get up and move around some at night, but for the most part they stay put. To attach themselves to a surface and help protect themselves from predators, bloodworms make a tube to live in. The tube is made out of bits of mud, mulm, algae or whatever is available. They sort of stick stuff together with spit and build a tube around themself. The larva undulates its body to create a current flowing through the tube which brings in food and washes away waste. You have probably seen these tubes but may not have taken much notice. They are about a half-inch long and either straight or crescent shaped. Curious? Set a pan of water outside and add a little finely-ground fish food or other meal. Within a few days you will see bloodworm tubes appear on the bottom and sides.

Frozen bloodworms can be purchased at any pet store with a frozen food section. The products I have seen have the bloodworms packed in water with various vitamins. They are commonly sold as small cubes in a 3.5 oz. blister pack or in 4 ounce frozen sheets. In our area, both cost about $15 per pound but they may be a little less in your community. You can find them on the Internet at $7-$8 per pound plus shipping but shipping small amounts of frozen food is an expensive proposition. Bloodworms are also available as a freeze-dried product but the fresh frozen form is thought by many to be better.

Depending on the species and age, there are about 40,000 bloodworms per pound. I haven't found bloodworm import/export figures and do not know how many commercial bloodworm culturing/harvesting companies there are. But, one Chinese company boasts that they ship over 400 tons of frozen bloodworms each year. That is 30 to 40 trillion bloodworms per year from one company.

We can easily grow and collect bloodworms at home. As noted, all it takes is a container of water with some sort of finely-ground meal for them to eat and make tubes out of. For sediment, I have used mud, crushed fish food flakes, rabbit food (the pellets dissolve and fall apart) and green water (water full of single cell algae). The small worm tubes appear in just a few days and they are full size in a little over a week. However, the timing will vary with temperature and the local midge species. To collect the bloodworms, just brush the sides and bottom of the container to dislodge the tubes and collect them in a fine-mesh net. The mesh opening of the net should be less than 1/32-inch (about 500 microns) to keep the smaller worms from going through. The tube material can be washed through while the worm is retained if the netting size is correct. However, you may want to consider giving your goldfish the whole tube. They will eat it all. Bloodworms grown in green water are encased in a tube which is largely composed of algae cells. Eating algae helps goldfish avoid swim bladder problems.

How many bloodworms can you grow? Well, it is reasonable to expect to get about one-hundred per square foot per week. A dish pan can make enough for a nutritious meal for goldfish tank each week. How much would you save each week by growing this precious commodity in a dish pan instead of buying it? About a nickel.

You often hear that feeding bloodworms and other natural foods may introduce disease into your system. I do not know how true this is and there are a lot of differences of opinion. The package of frozen bloodworms we can buy locally mentions three-step sterilization, bioencapsulation, packed in pure water, blah, blah. Some pathogens are killed by freezing but others are not. Everyone will have to decide for themselves. To my way of thinking, the most important factor in disease control is a strong goldfish immune system promoted by good nutrition and water quality. I use the same water for growing Moina and daphnia that I use for growing bloodworms. If there is a potential pathogen lurking there, the goldfish have been exposed to it since birth.

It is important to note that some people are allergic to bloodworms. The freeze-dried product seems more likely to cause an allergic reaction because the particles can easily become airborne. Some people report an allergic reaction to frozen bloodworms if they handle them, but feed them to their fish anyway using forceps or other instruments.

Why would we bother to buy frozen bloodworms, much less take the time to grow them ourselves? Because bloodworms are great nutrition for goldfish. Many experts consider them the best available food for our finned friends. For goldfish with a head growth (wen) like oranda, lionhead and ranchu, bloodworms and other natural foods are thought to be particularly important. Some serious goldfish keepers think that good head growth development is impossible without feeding bloodworms. It is likely that bloodworms have been harvested and hand-fed to goldfish for at least 600 years. However, you would not want to feed your goldfish with bloodworms exclusively because they are very rich in both protein and fat.

If you put a goldfish in that pan of water with the bloodworm tubes they will soon disappear. They will not disappear as fast as the goldfish can eat them though because bloodworms are masters of disguise. The bloodworm tubes may be obvious to us, but they are not-so-obvious to the fish. Fish find food through "scent" (sensing chemicals released by the forage or prey). Bloodworms also react to the scent of fish. When the scent of fish is high, the bloodworm stops undulating so its own scent does not escape from the tube and into the surrounding water. But, if we disturb the bloodworm or just slightly nick its tube, the fish will zero in on the scent and consume it immediately. It appears that fish stumble upon bloodworms by disturbing their tube as they pick through the sediment.

Why or how do bloodworms work so well? No one knows. Some say it is because of the high protein content. Bloodworms are about 60% protein on a dry weight basis but only 6% on a wet weight basis and when packaged in water. Fish meal is about 62% protein on a dry weight basis, wheat is about 13%, and most dry formulated fish foods are 32 to 42% protein. Others think that it is not so much the quantity of protein that makes bloodworms special but the kind of protein. Nutritionist would say that bloodworms must have a good "amino acid profile".

Amino acids are a class of nitrogen-containing acids. There are almost 100 different amino acids and about 20 of these are used by most animals. Goldfish can synthesize (make from scratch within their bodies) some amino acids. These are usually called dispensable amino acids. Others can be synthesized by the goldfish, but not fast enough to meet the demand so they need to be available in the food as well. These are usually called indispensable amino acids. Others cannot be synthesized by the goldfish at all and must be available in the food. These are called "essential amino acids".

Goldfish, like other animals, use amino acids to build proteins. Various amino acids are attached together to create various proteins. Each type of protein must be built by linking together a chain of amino acids in precisely the correct order. Every animal uses protein to build new tissue as it grows. They also use protein for cell repair and to build gametes (eggs and milt) for reproduction. Proteins are used in lesser amounts for the production of hormones, enzymes and some of the other materials needed for body function. There are many different types of proteins with many different functions in the body.

Amino acids are said to be the "building blocks" of protein. Maybe it's a generational thing, but I think of "building blocks" as small wooden cubes with the alphabet letters printed on one side, a number printed on another side and pictures of zoo animals printed on other sides. When you build something out of wooden blocks, the blocks are all the same size and shape, and are essentially interchangeable. To help understand why certain foods and feed ingredients work so well, we need to think of amino acids not as building blocks, but as Lego blocks.

Like amino acids, there must be 100 different types of plastic Lego blocks and pieces and about twenty of them are essential for building most Lego projects. Like amino acids, they can all attach to one another. Building a Lego project out of Lego blocks is like building a protein out of amino acids.

Imagine you need to build a variety of small Lego projects (proteins) with Lego blocks (amino acids). Each little project must look exactly like the picture in the Lego instruction booklet (your internal protein-building blueprint). First, you are given a bunch of completed Lego projects (food protein) which you must disassemble (digest). Then you are to put the Lego blocks back together in the shape of the many small projects as depicted in your instruction booklet (the particular proteins you need for growth, repair and reproduction). You have a variety of Lego blocks to work with after disassembling (digesting) the old projects. There are blue Lego blocks with eight bumps, some of the red kind with four bumps, some of the green one which is only half as tall and has six bumps, etc.

You start building your proteins as prescribed in your internal instructions. Everything goes pretty well at first. However, if the various types of Lego blocks you start with (the essential amino acids in the food you eat) do not occur in the same proportions as the Lego projects you are trying to make, you will run out of certain types of blocks (certain types of amino acids). If you need a blue Lego with eight bumps to finish building one of the proteins but all the blue ones have already been used, then you must wait until more food is digested and hope there will be a blue one in there. Conversely, if your food has a lot of red Lego blocks with four bumps but the proteins you are making do not require the red ones, then those amino acids are sort of wasted. That is, some components of the protein in the food you eat are not being utilized to build new proteins for growth, repair and reproduction.

As noted, goldfish can synthesize dispensable amino acids. However, making amino acids from scratch requires more energy than simply disassembling food protein to obtain the needed amino acids. Therefore, if all needed amino acids (dispensable, indispensable and essential) are available in the food and in the correct proportions, then the goldfish can function at peak efficiency. At peak efficiency the goldfish's growth, repair, reproduction, etc. will be maximized.

This is why you cannot evaluate a particular food by the quantity of protein alone. A food may have plenty of protein, but if it does not have the right proportion of the various amino acids needed by goldfish, then much of that feed protein sort of goes to waste. Amino acids which cannot be used for growth, repair and reproduction may be used as an energy source preferentially to carbohydrates and fat. When used as an energy source, amino acids are converted to ammonia and are excreted into the water.

So, how do we determine the optimal proportions of amino acids in the diet? It is a very complex puzzle which must be unraveled systematically with feeding trials. In each trial a particular amino acid is absent or deficient in the experimental feed and fish growth is compared to some standard control feed. Once the optimal proportion of amino acids is determined, then food stuff ingredients with known amino acid composition are blended to provide those proportions in the feed. This is an expensive and time-consuming process. The results are confounded by the fact that the optimum amino acid profile changes as a fish grows and matures. Because of the amino acid sources (crystalline amino acids) which are used in chemically-defined experimental diets, there are also some inherent problems with the digestibility. In these feeding trial with chemically-defined diets, the growth is never as good as it would be in own tanks and ponds; even with the control diet which is supposed to contain all the needed amino acids. To determine the optimum amino acid profile using natural feed ingredients is even more difficult and time consuming.

We know a lot about the amino acid requirements of humans (of course), poultry, swine, and other important agricultural products. We even know quite a bit about the amino acid requirements of trout and salmon. We know a little about the requirements of juvenile common carp being grown for human consumption. These carp studies were done with chemically-defined diets. For goldfish, about all we can do is assume that their requirements are similar to juvenile common carp. Based on the work by Dr. T. Nose in Japan, the U.S. National Research Council compiled recommended levels of essential amino acids in the feed given to juvenile common carp being grown for food (see table).

We also know something about the amino acid profile of bloodworms thanks to work done in Poland in the 1970's (see table). We see that bloodworms have less than the recommended amount of phenylalanine, histidine, valine and lusine. High quality white fish meal by comparison (see table) is only lacking in phenylalanine and methionine. Wheat is lacking in phenylalanine, lysine, threonine and methionine. But as we now know, we do not want a food source to have an excess of any particular amino acid either. Going strictly by the numbers, the standard deviation from the recommended amino acid profile for common carp is about the same for bloodworms, fish meal and wheat. But, practical experience and intuition tells us that bloodworms are a better diet than fish meal and fish meal is better than wheat.

Amino acid	Common Carp Recommended Diet [1] (% of protein)	Bloodworm [2] (% of protein)	White Fish Meal [1] (% of protein)	Wheat [1] (% of protein)
Phenylalanine	6.5	2.9	3.8	4.8
Histidine	2.1	0.8	2.2	2.3
Valine	3.6	1.9	4.9	4.5
Lysine	5.7	5.5	7.3	2.8
Arginine	4.3	4.8	6.8	4.9
Threonine	3.9	2.7	4.1	2.8
Leucine	3.3	4.1 *	7.3	6.8
Methionine	3.1	2.9	2.7	1.6
Isoleucine	2.5	4.1 *	4.3	3.9
Tryptophan	0.8	2.8	1.0	1.3
Cystine	??	2.8	1.2	2.1
Tyrosine	??	2.2	3.1	3.3
Glycine	??	2.2	??	??
Serine	??	4.2	??	??
Aspartic Acid	??	10.4	??	??
Glutamin Acid	??	8.5	??	??
Alanine	??	7.7	??	??
Proline	??	1.3	??	??

* Leucine and Isoleucine combined is 8.2% of protein.

[1] Committee on Animal Nutrition, Board on Agriculture, National Research Council. 1993. Nutrient requirements of fish. National Academy Press. Washington, D.C.

[2] B. Czeczuga and M. Gierasimow. 1973. Investigations on Protein Amino Acids in the Larvae of Chironomus Annularius Meig (Diptera - Chironomidae). Hydrobiologia 41(2): 241-246.

To make matters worse, there are some problems with using the juvenile carp studies as a basis for developing goldfish diets. We know that the overall protein requirement tends to decline with age. Fry and juveniles need higher levels of protein because they are rapidly growing. Carp being grown for consumption are marketed as young adults because the growth rate and profitability declines as the fish matures. For goldfish, we are interested in both fast growth and long life. The diet studies on common carp did not evaluate the effect on longevity or the needs of adult goldfish. I hope, but do not know, that goldfish feed manufacturers are conducted their own proprietary studies to address these issues.

With imperfect amino acid requirement data, some intuition must be thrown into the mix when formulating goldfish diets. In general, we know that protein sources derived from aquatic animals and aquatic plants are more likely to have desirable amino acid profiles than protein sources derived from terrestrial animals and terrestrial plants. This means that things like fish meal and shellfish meal are better diet constituents than things like blood meal, poultry by-products meal, feather meal, corn, wheat and soybean. A problem is that fish meal and shellfish meal are very expensive ingredients. In addition, a certain amount of plant-derived starches (wheat gluten for example) are needed to bind a feed pellet together in the manufacturing process.

Most of the goldfish pellets I can buy in my local pet stores contain a mix of fish meal, wheat and other grain meals, vitamins and minerals. However, the best (or, rather the most expensive) goldfish pellet I can buy locally also contains krill meal (a small shrimp-like creature), seaweed meal and Spirulina (an algae). Of course, feed companies do not want to discuss their trade secrets and it is unclear whether these expensive ingredients from aquatic sources are there primarily to improve the amino acid profile or as color enhancers.

But, back to bloodworms. Circumstantial evidence suggests that bloodworms are an extraordinary food source for goldfish. Or, at least, bloodworms enhance the results achieved with formulated pellets alone. The assertion that this effect is the result of the high protein level in bloodworms seems unfounded. The assertion that this effect is the result of the amino acid profile of bloodworms may be true, but it cannot be substantiated by a non-nutritionists like myself with the available data.

Is there a food source which is better than bloodworms? We do not know and can only speculate. This part is a little far-fetched, but… Bloodworms were already present when carp appeared about 200 million years ago. Bloodworms are a dominant life form in the shallow freshwater habitats where carp evolved and is the most prevalent macro-invertebrate there. In other words, the goldfish ancestors evolved in a habitat where bloodworms are one of, if not the most, readily available food source. It may not be an accident or happenstance that of bloodworms are ideally suited for goldfish growth and reproduction. It may be programmed into their evolutionary biology.

Regardless of how or why, those that feed bloodworms to their goldfish seem to agree that they work. For about three bucks you can try it yourself. Oh, and one thing I forgot to mention - the fish absolutely love them.