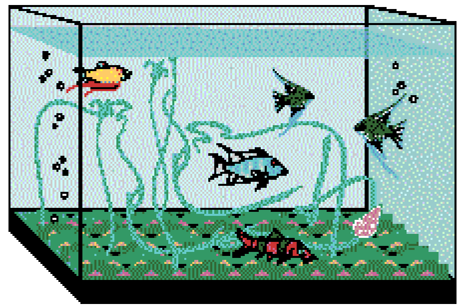
A Bottleneck in Nature



The Earth is not getting larger. However, every year there are more and more humans wanting more and more non-renewable natural resources, and every year the Earth's non-renewable resources are being lost. The Earth is exactly like an aquarium kept in your living room, except that it is larger, and is kept in empty space. You cannot just keep adding fish to any aquarium indefinitely, and you cannot remove a little water each day indefinitely. In the same way, at some point the human demand upon nature must be stabilized, and the Earth's non-renewable natural resources must be conserved.

Because of this insight, we are now going to talk about phosphorus. This is *not* because backyard naturalists need to know a lot about phosphorus, but rather because of these two points:

- We should all become accustomed to analyzing the world around us and pinpointing critical situations needing our attention (*a rare species requiring protection, a source of pollution that should be stopped, a local plan to convert a forest to a parking lot that must be protested...*)
- We should become accustomed to seeing the world we live in as a web of life with some parts more fragile and more vulnerable than others.

OK, here we go with phosphorus...

Maybe you've had this experience: You're sweating and some butterflies or bees land on you and begin "drinking" your sweat. Sometimes certain butterflies get so involved in their sweat-drinking that you can actually pick them up by their wings. What's going on here?

What's happening is that these creatures need mineral elements in your sweat such as potassium, magnesium, and calcium. Their need for these minerals is so great that if they didn't have them they'd die. And these minerals are often not easy to acquire in nature.

This may strike you as strange, especially if you know that these mineral elements are prime ingredients of the Earth's crust. If you could scoop up the entire Earth's crust -- the several-miles-deep rock and mineral portion of we live on -- and separate it into the mineral elements it's made of, about 3.6% of it would be calcium by weight, 2.6% potassium, and 2% magnesium...

So, if these minerals are so common wherever there is ordinary dirt and rocks, why would butterflies and bees get so excited about finding some in our sweat?

The problem is that these minerals dissolve in water. They're soluble. When it rains, if an atom of these minerals comes loose from the piece of rock or soil particle it's probably spent millions or billions of years stuck in, that atom (that *ion*, if you want to be technical) will be washed away, dissolved in the water. Probably it will flow into streams, then rivers, then finally into the oceans. Every rain flushes soluble mineral elements out of the landscape, into our streams.

Not all liberated mineral atoms rush immediately to the sea. An important "detour" a newly freed mineral can make is to be latched onto by a living organism. Maybe the root of a plant will take in the water the atom is dissolved in, and then the atom may well become part of that plant's body. And if that plant is eaten by an animal, the atom may become part of the animal's body.

In fact, *all life needs these minerals*. Life simply doesn't happen without them. We're not just speaking of calcium, potassium and magnesium.. The last time I looked, these mineral elements were all absolutely required for *plants* to stay alive: **nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, chlorine, iron, manganese, zinc, copper, molybdenum**, and **nickel**.

For example, at the heart of *every* molecule of chlorophyll, there is an atom of magnesium, so without magnesium photosynthesis is impossible, and without photosynthesis green plants and higher animals that eat the plants can't exist. Every protein molecule has an atom of nitrogen in it and you know that there can't be muscles and many other things without protein. There can't be red blood cells without the iron in hemoglobin molecules... On and on it goes with each required mineral element.

Once it sinks in that these mineral elements are really *needed* for life -- not like "I need a hamburger with pickles" but like "I need air" -- then this question arises:

Which of the above mineral elements do organisms stand the greatest chance of running out of?

The answer is: **Phosphorus**.

In fact, Isaac Asimov, an important science writer, has defined phosphorus as "life's bottleneck." This is true even though phosphorus is by no means the rarest mineral element. If you have a miniscule amount of something but only need a tiny, tiny bit of it, then that's less critical than if you have a fair amount of something, but you need a lot of it...

Asimov noticed that some mineral elements are more common in organism bodies than in the surrounding environment. Obviously that organism has needed to *concentrate* that element in itself. The degree of concentration of that element in the organism's body, then, becomes a good indication of these two things:

- how much organisms need that element
- how available it is in the environment

Asimov noted that phosphorus composes about 0.12% of an average soil, yet a much greater percentage of an alfalfa plant's body, about 0.7%, is phosphorus. Therefore, the "concentration factor" for phosphorus is about 5.8 (0.7/0.12).

No other mineral element even comes close to having a concentration factor as great as phosphorus's. The closest is sulfur with 2.0, then chlorine with 1.5. All the rest have less than a factor of 1.

Therefore, if there are more and more organisms needing mineral elements, or if the living ecosystem is more and more depleted of its resources, which mineral element will come into short supply first?

Phosphorus.

And since phosphorus is a mineral element that organisms absolutely must have to stay alive, it doesn't much matter whether there is enough of all the other elements...

Yet phosphorus leaches from our soils, is removed from the land in the crops we harvest, and flows down our drains whenever we use phosphorus-rich detergents or flush the commode (phosphorus was in the land, then in the agricultural crop we ate, the phosphorus passed through us, and now we're flushing it away...) and phosphorus ends up flowing into our streams and rivers and ultimately to the oceans. There it settles into mud and is not returned to the land except by geological processes requiring millions of years. Well, there are minor detours: Some phosphorus will bond with mineral particles, some of it reaching the ocean is returned in the droppings of sea birds and in fish caught there and eaten inland... but for the vast majority of phosphorus atoms, once they become dislodged from their rock and mineral parents they begin a one-way trip to the ocean.

However, we're not going to run out of phosphorus anytime soon. There's no need to start hoarding phosphorus.

But it *is* time to become concerned about the long-term effects of the enormous worldwide loss of essential mineral elements through soil erosion and the lack of recycling of our organic wastes. It *is* time to begin seeing the Earth as a very vulnerable and beautiful aquarium of fixed size set in empty space...

Here's the generalized "phosphorus cycle," with the two red boxes showing where phosphorus is lost from the ecosystem -- where it begins its journey to the ocean.