

Sealed Microcosm Primer

A working sealed microcosm is an example of recycling at all levels. Here we study and attempt to design and build such an ecosystem. The success of such a venture will depend upon how well the recycling works. If a major cycle such as the CO₂, O₂ and Energy cycle is not balanced (such as a situation in which there is more respiration than photosynthesis), then some products (i.e. CO₂, a product of respiration) will build up to lethal levels to the microcosm inhabitants or perhaps starvation will occur as reactants are used up (i.e. CH₂O, the food). We as designers need to pay attention to as many cycles as possible to assure success.

The CO₂, O₂ and energy cycle

Photosynthesis and respiration form a perfectly balanced cycle because they recycle each others products. The driving energy source is light energy being transformed by plants into chemical energy which is then transformed into mechanical energy to drive the engines of life, and this is finally converted into low-grade waste heat which is not recycled. Sunlight is the only input required for this system to continue functioning.

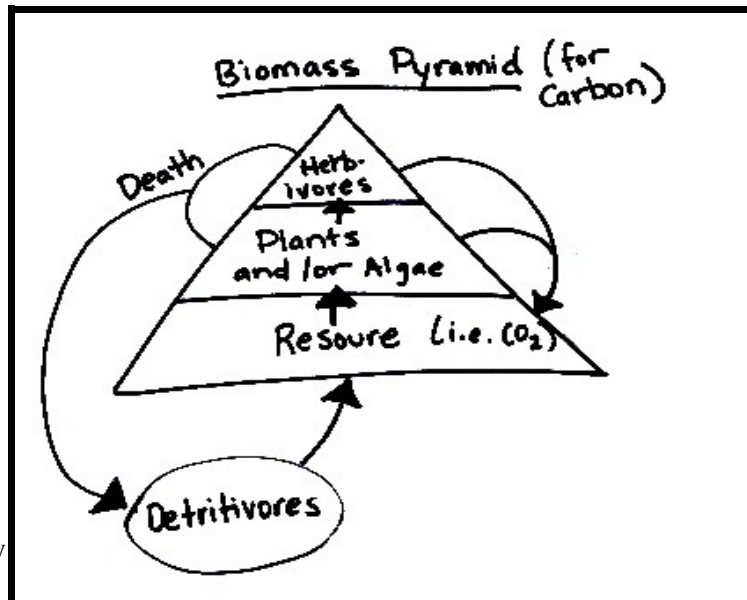
Photosynthesis:

$O_2 + CH_2O \rightarrow H_2O + CO_2 + \text{energy for animals}$
(^energy rich carbohydrate:
sugars, starches and cellulose -- food)

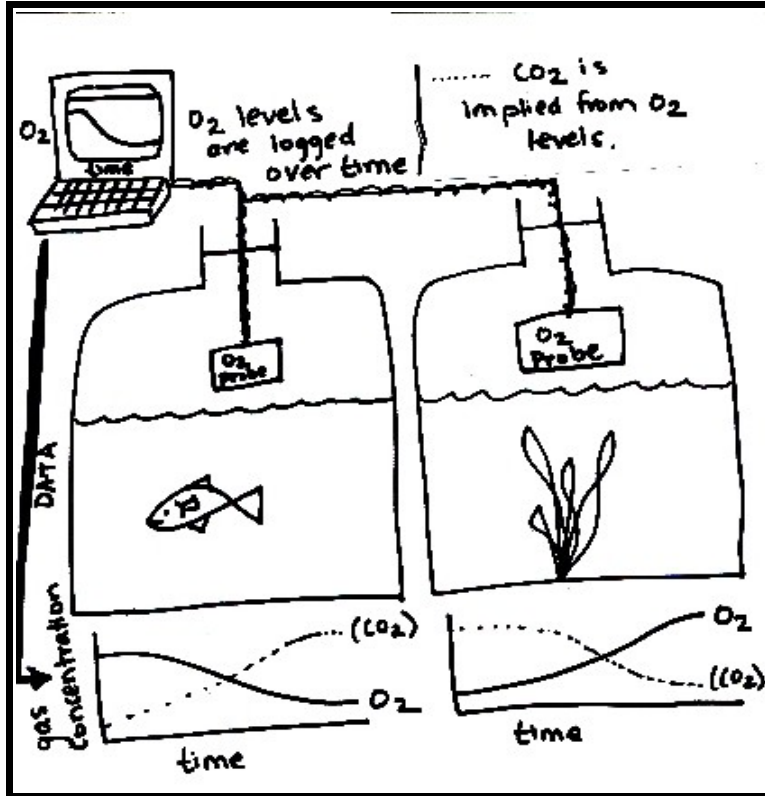
Respiration:

$H_2O + CO_2 + \text{sunlight energy} \rightarrow O_2 + CH_2O$
(energy rich carbohydrate ^)

There are many other cycles which need to be balanced to maintain the health of a closed microcosm. For example nutrients such as nitrogen and phosphorus are cycled. Living (and dead) biomass is a complex mix of nutrients such as carbon, nitrogen (N) and phosphorus (P). Lake water has microbes which recycle urea (CON₂H₄), nitrite (NO₂⁻), nitrate (NO₃⁻) and ammonium (NH₄⁺). These microbes glean energy from converting ammonium to nitrite or nitrite to nitrate. The plants and algae take up nitrate and use it for growth. If the right balance of microbes that recycle nitrogen and phosphorus are not present then the above products (i.e. urea, ammonium or nitrite) will eventually build up to toxic levels and destroy the lifeforms in the sealed flask. It is our job in this lab to see if we can get the right mix of organisms to recycle the organic matter and other waste products. The bacteria which recycle nitrogen are often found in lake water and mud. The bacteria which break down dead biomass into reusable nutrients are often found in mud too. These microorganisms are called detritivores because they eat detritus (i.e. dead biomass). Without detritivores on earth, we would all be wading through piles of dead bodies. Fungus (mold, mushrooms, yeast) is a great example of a detritivore.



We must make simplified foodwebs in our jars, ones where the top trophic level is an herbivore (plant-eater). There simply isn't a high enough carrying capacity in our small sealed flasks to support a predator sustainably. You may be able to observe herbivore-algae boom and bust cycles in the jars. As a biochemical product builds up, the algae which exploits that product as a resource will often explode in numbers. Once the algae attain high numbers, then the herbivores which consumes the algae will thrive and deplete the numbers of algae. In order to



avoid extreme cycles of boom and bust that could cycle out of control and kill off most of the inhabitants of the sealed microcosm, we should be conservative with the amount of biomass in each level that we introduce to the microcosm, and attempt to create deserts rather than jungles. These deserts will then grow until the nutrients are exploited to the degree that the available amount of limiting nutrient permits in balance with the Redfield ratio of 106:16:1 C:N:P.

In order to develop an intuition for how much biomass to add to our miniature ecosystems, we have instrumentation to measure concentrations of O₂ and CO₂ gas. We will attempt to quantify the rates of change of these gases to discover the rates of production and consumption of these gases by living matter. For example if we measure how many grams/day of O₂ is consumed by a healthy goldfish of so many grams weight and how many grams/day of O₂ is produced by a healthy plant of a known weight, then we

should be able to at least in the short term balance the production and consumption of oxygen in the system and perfectly recycle the O₂ (and CO₂ by implication) so that the inhabitants of the jar survive.

Also important other details pertaining to O₂ and CO₂ to assure their availability to the living organisms are diffusion, convection as air-sea gas exchange. We will do some experiments that will show some of the details of that. The head space in the jar is important to the ecosystem function, because air stores 27 times more oxygen per volume than water does. It is important that there is enough of a reservoir of oxygen in the sealed microcosm to prevent the water from becoming anaerobic and killing off much of the life.

