Some potential answers or hints for Questions for Thought posed in Freshwater Ecology: Concepts and Environmental Applications

Chapter 1

1) Why are you interested in studying aquatic ecology, and is such study important? *I was interested in the outdoor world from a very young age and I had a great limnology teacher in college. The study of aquatic ecology is important because central environmental issues revolve around freshwater systems, and dealing with these issues requires a basic understanding of the science. Plus, aquatic habitats are great fun to work in.*

2) What is the difference between fluxes and compartments in water cycles, and what types of units typically are used to describe them? *Compartments are standing stocks and units are in volume. Fluxes are the rate of movements between the compartments and units are in volume per unit time.*

3) What are some potential economic benefits to maintaining water quality? *Economic benefits include maintenance of ecosystem services such as sewage disposal and removal of wastes from habitats. Water provides irrigation for many of the world's crops and drinking water for humans. Industry is based on availability of clean water. Fisheries are economically important. Non-consumptive uses such as recreation and eco-tourism associated with aquatic habitats generate significant economic activity.*

4) What are the potential dangers in approaching conservation of aquatic resources from a purely economic viewpoint? *If an organism is determined to have little or no economic value, then causing its extinction would be more likely. The concept of maintaining biodiversity because humans do not have the inherent right to destroy it is important in conservation.*

5) List three "tradeoffs" that potentially are involved in protecting native species in regulated rivers by attempting to mimic natural water discharge patterns. *Releasing waters in large flood pulses may cost utilities and dam operators money. Low flow periods may be a natural part of river ecosystems, but such conditions may not allow for navigation on larger rivers. Changing dam operation procedures may harm desirable species found in the reservoir.*

Chapter 2

1) Why is less of a temperature difference required for stratification (stable layers of different density) to occur in tropical lakes than in temperate lakes? *There is a greater difference in density per degree temperature difference at the warmer temperatures typical of tropical lakes.*

2) Why do bacteria generally sink more slowly than dead fish, even when they both have approximately the same density? *Reynolds number is low, viscosity high, so the effect of gravity is counteracted by viscosity more for the bacteria than the fish.*

3) If you wanted to simulate a 1-μm-diameter spherical bacterium swimming at 10 μm/sec with a 1-cm-diameter sphere, how fast would you have to move the sphere to achieve the Reynolds number that the bacterium experiences? *We want to equalize the Reynolds number in both, so we set the right side of the equation for Reynolds number equal for both situations. Since dynamic viscosity and density remain the same, and characteristic length increases 10,000 times, from 1 μm to 1 cm, the velocity must decrease by the same factor. The 1 cm diameter sphere would have to be moved at 0.0001 μm/ sec.*

4) Flow is slower in a small pipe than in a large pipe, given the same water pressure gradient. Explain this difference with respect to Reynolds number and viscous force. *At lower Reynolds numbers in the smaller pipe viscosity is greater. More force (water pressure) is required to move the fluid through the smaller pipe at the same velocity. Given the same water pressure, water will flow more slowly through the smaller pipe.*

5) Why are small swimming crustaceans not nearly as streamlined as larger fish? *At the smaller Reynolds number turbulence is less important. Streamlining thus has less of an effect and is not selected for as strongly in smaller organisms.*

6) Why might a lake with a large surface area mix more often and more deeply than a smaller lake? *The wind can have a greater influence on a larger body of water because it has more distance to act on the water.*

Chapter 3

1) Why would you expect transport diffusion to occur in a still glass of water, if evaporation was occurring at the surface and how would you keep such transport diffusion from occurring? *Evaporation cools the surface of the water. The cooler water will have a greater density and mix down into the glass, and the warmer water from below will replace it. These currents will cause rates of diffusion that exceed molecular diffusion.*

2) Why do aquatic insects in torrential streams have reduced gills? *Higher velocity decreases the thickness of the diffusion boundary layer. This leads to more rapid transport of O_2 into the gills and CO_2 away from the gills. Less surface area is needed to obtain sufficient gas exchange for survival. In addition, large gills increase drag and increase the probability*

that an insect will be swept away

3) Calculate the surface area to volume ratios for a sphere, a cube, and a right circular cylinder (1 cm high), each with a volume of 1 cm^3. Relate these to diffusion of materials to cells of different shapes (*r* is the radius, *h* is the height, *S* is the surface area, and V is the volume) for a sphere $S = 4\pi r^2$, $V = 4/3\ \pi r^3$ and for a right circular cylinder $S = 2\pi$ r h and $V = \pi r^2$ h). *Area to volume ratios for the sphere, cube, and cylinder are 3, 6, and 3.54 respectively. A sphere has the lowest surface area to volume, so diffusion into the sphere would be the most limited, the cube has the highest surface area to volume ratio, so would experience higher diffusion rates. The cylinder would be intermediate. If the length of the sphere is tripled, but the volume held the same, A:V would be 6.13, and inward diffusion would be greater (i.e. the average distance between inside the cylinder and the outside edge would be less).*
4) Why might large rivers generally have greater attenuation coefficients than large lakes? *Large rivers tend to be turbid, large lakes tend to be clear.*
5) If objects at the surface of a lake are blue, black, red, or white, what color would they appear if they were viewed at 20-m depth in a oligotrophic lake? *They would appear blue, black, black and blue-green respectively.*
6) Use the data plotted in Fig. 3.6 to demonstrate that you obtain a straight line if the natural log (ln) of light is plotted against depth. *It works, try it yourself!*

Chapter 4

1) Why would understanding the hydrodynamics of groundwater be important when an oil spill occurs on land (e.g., leakage of a gasoline or oil storage tank)? *If there is enough oil, and the soil is permeable, the contaminants will move to the surface of the groundwater. The contaminants will then be transported along with the flowing groundwater, so understanding the hydrodynamics will allow for prediction of where the spill will spread.*
2) Why might understanding the application of Darcy's law to sediments under a wetland be important when calculating a water budget for a wetland? *Darcy's law can be used to calculate how quickly water will seep out of the wetland.*
3) How could global warming alter precipitation patterns throughout the world and the recharge of groundwater aquifers? *It is difficult to predict. Precipitation will increase overall, but may decrease in some areas. Evapotranspiration will certainly increase with increased temperature. Since groundwater recharge requires precipitation to infiltrate, and that is a function of timing and amount of precipitation, and of rate of evapotranspiration, specific predictions are questionable.*
4) Do you know of any local wetlands that are endangered or have been drained in your lifetime? *Many, everywhere.*
5) How can temporary wetlands in arid habitats be extremely important to wildlife? *Water is very limiting to wildlife in arid habitats, and such wetlands may be the only source of surface water in some areas.*
6) Why do extensive wetlands exist in the high Arctic, even though annual precipitation is similar to that in many temperate or tropical deserts? *Precipitation is low, but evapotranspiration is low because of low temperatures. Permafrost keeps water near the surface. These two features lead to extensive wetlands in areas with low slope.*

Chapter 5

1) Why might some regions in deserts serve as runoff sinks (i.e., have more water flowing in than out)? *If evaporation and loss to deep groundwater exceeds precipitation and inflow, then more water will flow in than out.*
2) How can levees act as dams to upstream areas during floods? *Levees constrict flow, causing water to back up upstream from them and increasing upstream flooding.*
3) Why does channelization increase the movement of bed load during floods? *Channelization increases water velocity, which leads to greater movement of bed load.*
4) How may the amount of suspended materials in streams alter the rates of photosynthesis of organisms attached to the stream bottom? *Suspended materials intercept light, lowering photosynthetic rates.*
5) How might vegetative characteristics in a watershed relate to stream flow in terms of total amount and in terms of how many floods occur per year? *A heavily vegetated watershed will retain water and loose more water back to the atmosphere via evapotranspiration. This water retention will lower severity of floods, but may sustain baseflow after floods for longer periods.*
6) How does frequency and predictability of flooding relate to the possibility that stream organisms are adapted to flooding? *If flooding is too frequent, organisms are unlikely to adapt because they cannot even survive long enough to reproduce. If flooding is highly unpredictable (ie. once every 50 years), it exceeds generation times of most stream organisms and adaptations to flooding may be difficult to find. A stream that regularly floods during specific times of year may be most easily adapted to. For example, organisms could be selected for that find refuge in the sediments during predictable times of flood.*

Chapter 6

1) Why is it sometimes difficult to assign one single geological explanation for a lake's origin? *Several geological processes may act in concert. For example tectonic basins may be altered by glaciation.*
2) Why is a lake with a high value for D_L likely to have smaller waves than a lake of comparable surface area with a D_L close to 1? *The greater the shoreline development index, the more likely the fetch will be shorter, because a more dissected shoreline means less open water. Also, trees on the banks will shelter the lake from wind and with more shoreline, more trees will be closer to any specific section of lake.*
3) Why do more lakes occur farther from the equator? *Glaciation is a major process that forms lakes.*
4) In which order (from greatest to least) should lakes be ranked with respect to the ratio of maximum depth divided by the mean depth: tectonic, glacial, and fluvial? *A lake with a flat bottom should have the maximum value for maximum:mean depth. Tectonic lakes tend to be old with steep sides, so should have the least relative variation in lake depth. However, they may have very deep crevices, leading to a high ratio. Glacial lakes should have fairly regular bottoms (i.e. bowl shaped), maximum depth should not deviate much from mean depth. Fluvial lakes should be the most recent and variable in depth, though as they fill in and become wetlands they may have fairly flat bottoms.*
5) Langmuir circulation cells concentrate particles slightly more dense than water below the surface of the water: Where will these particles be concentrated and why? *The particles will be concentrated in lines along the upwelling portions of adjacent cells.*
6) Under what conditions would thermal stratification lead to anoxia in the hypolimnion? *Anoxia in the hypolimnon will occur when oxygen demand exceeds diffusion across the metalimnion plus the amount in the hypolimnion upon stratification.*
7) Explain why some rivers flowing into lakes flow down into the hypolimnion, some flow across the surface, and others flow into the metalimnion. *Rivers flow to the depth closest to their own density. For example cold rivers (relative to lake temperatures in the hypolimnion) should flow into the hypolimnion and very warm rivers across the top of the epilimnion.*

Chapter 7

1) Why might legislation designed to prevent extinction of species require a precise definition of a species? *A legal challenge against efforts to protect an organism may consist of the argument that the endangered population is not unique taxonomically.*
2) Why did the inclusion of mitochondria and chloroplasts in cells of Eukarya represent a sudden large increase in complexity of cells? *These organelles originally each had their own chromosome for the physiological processes utilized by the hosts. Eventually many of these genes were incorporated into the eukaryotic genome, or if they were redundant were lost. The important aspect is they allowed for compartmentalization of specialized physiological functions such as photosynthesis and respiration from the rest of the cell, and simultaneously caused a big jump in cellular complexity.*
3) Why might freshwater invertebrates have fewer species as a whole than marine invertebrates? *There has been less continuous time for evolution in most freshwater habitats.*
4) Why does lateral transfer of genetic material among widely disparate organisms (e.g., plants and bacteria) cause difficulties for molecular taxonomists? *Taxonomists cannot be sure if phylogenetic trees constructed with specific gene sequences are correct because the modification of the genome is not purely by accumulated evolutionary changes.*
5) Can you think of more specialized habitats than those listed on Table 7.3? *Yes, many more specific habitats can occur. For example the bracts of bromeliads and the splash zone near waterfalls.*
6) Is taxonomy fixed when a species is described or do perceived taxonomic relationships among organisms change over the years as more information becomes available? *Taxonomy is a continuously changing construct as more information is accumulated. The taxonomic of even fairly well known organisms such as fish and birds changes upon occasion.*
7) How would morphological plasticity interfere with taxonomic identification? *Organisms of the same species may appear to belong to more than one species if morphology is different enough between individuals.*

Chapter 8

1) Do more types of viruses exist than species of organisms on Earth? *If each organism has several specific viruses (likely), then yes.*
2) Should separate taxonomic definitions of species be used for microbes than those that are used for animals? *Probably, they already are, and microbial taxonomy must be more heavily based upon molecular methods.*
3) Why are there no known fish-pollinated aquatic angiosperms? *Evolution does not always provide solutions to problems (such as how to pollinate under water) that would obviously work.*

4) How does stability of the benthos determine if benthic systems are dominated by microalgae or by macrophytes? *Most macrophytes need roots to stay in place, in very unstable sediments macrophytes cannot become established but microalgae (periphyton) can.*
5) Should molecular taxonomy methods be more useful for aquatic angiosperms or unicellular algae? *They should be used more with unicellular algae because they exhibit less morphological variation than macrophytes.*
6) Why are floating leafed macrophytes relatively rare on large lakes? *Waves and turbulence cause too much physical damage and move them to shore.*
7) How do carnivorous plants commonly found in nitrogen-poor wetlands compete successfully for nitrogen? *They digest bugs that are rich in nitrogen.*

Chapter 9

1) What constrains Crustacea from reaching the size of humans? *It is mechanically less efficient to connect musculature to an exoskeleton at larger scales. Crustacea also have less developed circulatory systems that do not carry blood to a large body volume as efficiently.*
2) What groups of invertebrates do you think are most likely to contain undescribed species? Why? *The small insects, because they are not obvious and such a diverse group. Other groups such as the nematodes, gastrotrichs, and tardigrades are less studied and less obvious so may contain numerous undescribed species.*
3) Why do most aquatic insects leave the water to mate? *It allows for dispersal and gene flow. Also aquatic insects arose from terrestrial forms that have winged reproductive adults. It is a disadvantage to have delicate wings underwater.*
4) Why has behavior evolved to be more complex, but biochemistry less complex, in animals in comparison to microorganisms? *Regulation of large multicellular structures requires fine control over metabolism and biochemistry, which does not allow for as much biochemical complexity. Individual cells of multicellular organisms must be programmed for particular functions, and must be able to perform that function reliably. More is invested in each offspring so there is a greater cost of loosing descendents and less room for biochemical variation. Animals partition their habitats based on behavior in addition to biochemistry.*
5) Why are aquatic insects rare and not diverse in marine habitats relative to freshwater habitats? *Most aquatic insects entered freshwater habitats from terrestrial habitats. There is more fresh than marine water in contact with terrestrial habitats.*
6) Why are animal assemblages of lakes generally less diverse than those in streams? *Lakes tend to have a shorter evolutionary history than larger watershed (but old lakes such as Baikal and Tanganyika are an exception).*
7) How have animals adapted to subsurface habitats? *They have increased sensory adaptations that do not rely on sight. They have lost eyes and pigmentation because these cost a small amount of fitness and are not used in subsurface habitats.*
8) Why is lifespan tied to the utility of various freshwater animals for use in biotic assessment indices? *Biotic assessment requires integration across timescales. Microbes and algae have short life spans and respond quickly to changes in the environment. Invertebrates have intermediate life spans and integrate over weeks and months. Fish and large macrophytes may integrate over years.*
9) Why are there more species of Crustacea than mammals and various birds? *They have earlier evolutionary origins and have had more time to evolve. They have also been successful enough to avoid extinction.*
10) Why do fish that are ambush predators have a different morphology than piscivorous species that forage in the pelagic zone? *Ambush predators need one quick burst of speed, so they have muscular bodies with a large tail. Pelagic species need to cruise quickly over long distances, so they have torpedo shaped bodies.*

Chapter 10

1) Why are temperate lakes generally relatively species poor? *They were glaciated fairly recently, and little time has passed for colonization or evolution.*
2) What are the evolutionary advantages of very long diapause periods? *If a habitat is only very rarely suitable for successful growth and reproduction, a long diapause may be useful.*
3) Are there more species of large than small animals? *There are more species of small animals (insects) on earth than any other type of plants or animals.*
4) Should conservation be based on local diversity (e.g. if a species is rare in one state and common in another, should it be conserved where it is already rare)? *This is a value judgment. There are some data that the margins of a species distribution are important points for fixation of adaptive genes.*
5) What is the benefit of an ecosystem-based method of conservation? *Organisms need intact ecosystems to survive. If you save the habitat (the functioning ecosystem), you are more likely to save the species.*

6) Should DNA samples of endangered species be stored? *Yes, but not in lieu of conserving the species in their natural habitat.*
7) How might genetic diversity be different than species diversity, particularly in microbial species? *If there is considerable genetic redundancy (e.g. in a group of mammals) then species diversity may seem high, but genetic diversity low. In a group of microbes, they may look alike, but be different genetically.*

Chapter 11

1) Why are nutrients that are taken up by cells often preferred when in a reduced form, even when organisms inhabit oxidized environments? (Hint: Think of the conditions under which life evolved) *Oxidized compounds cost organisms more energy to assimilate than reduced compounds when they are taken from an oxidized environment, so the ability to utilize nutrients such as sulfur and nitrogen directly as sulfate and nitrate may confer a competitive ability. However, it is hypothesized that life evolved under moderately reducing conditions, which suggests that inorganic compounds were generally in reduced forms. Thus, at the time when organisms evolved biosynthetic pathways, the primary chemicals available were mostly reduced.*
2) Why do midge larvae that live in the profundal benthos of lakes often turn bright red when brought to the surface? *Bloodworms are bright red when exposed to surface oxygen because they live in a low-oxygen environment and have high amounts of hemoglobin to scavenge the low amount of oxygen that is available. The compound turns bright red when oxygenated at the surface.*
3) Why are aquifers in karst regions often oxic? *Limestone aquifers have large channels and rapid flow of water, which allows little time for microbial respiration to deplete oxygen.*
4) Why is oxidation of organic carbon by O_2 more efficient than anaerobic respiration? *The other electron acceptors (e.g. nitrate, sulfate) are at a lower redox state than O_2, and thus closer in redox to organic C so they release less potential energy when reacting with organic C.*
5) Dense periphyton mats can lift off of the bottom of a lake during the day, float to the surface, and then sink again at night. Why might this happen? *The rate of O_2 formation is great enough to form bubbles. These bubbles are trapped in the mat and float it to the surface. At night, respiration depletes the O_2, it goes below saturation, the bubbles re-dissolve into solution and the mat sinks back down.*
6) Winter fish kills from anoxia can occur in Arctic lakes that are not very productive, and do not freeze to the bottom. Why? *Unproductive lakes have low rates of metabolism, but remain ice-covered for many months. Eventually the O_2 is depleted. A similar lake in the temperate zone would have a shorter period of ice cover, and lower probability of oxygen depletion.*

Chapter 12

1) Why may global warming alter deposition rates of organic carbon in peat bogs? *This is a controversial subject. Warming will increase plant productivity and thus carbon input. Respiration rates will also increase as temperature increases. To further complicate things, precipitation and hydrology also change.*
2) Should wetlands be preserved even though they are a net source of greenhouse gasses? *Yes, they are an important source of biodiversity. Humans can control other sources of greenhouse gasses at a lower cost to biodiversity.*
3) Why might the microlayer at the surface of lakes be important in determining influx and efflux rates of lake water CO_2? *Atmospheric CO_2 enters or leaves lakes across the water-atmosphere interface. Just as with interfaces between solids and liquids, molecular diffusion may predominate at very small scales near the air-water interface. Factors such as waves, slicks of chemicals and particles at the surface, and heating currents all may alter the transport across this boundary layer.*
4) Do the processes of manganese reduction and iron reduction by bacteria have to occur in regions of different redox in the environment? *They do not have to happen in different parts of a redox gradient, however, iron reduction will generate slightly less energy than manganese reduction, thus manganese is depleted first at slightly higher redox values. This is because organisms that utilize the more efficient oxidant will be more successful competitors.*
5) Why is CO_2 more likely to limit production of benthic organisms than phytoplankton? *The diffusion boundary layer is a more important constraint at larger scales. The benthos has larger diffusion boundary layers than microscopic planktonic cells, thus the potential diffusion limitation is greater.*
6) Why is it important to know the pH when conducting experiments to measure photosynthetic rate with $^{14}CO_2$? *Photosynthetic organisms cannot use all forms of inorganic carbon at equal rates. The specific activity (amount of label per unlabeled molecule) is necessary to calculate absolute rates. If alkalinity is known than pH can be used to calculate specific activity.*
7) Why is alkalinity generally high in limestone watersheds? *The limestone dissolves in the water leading to high levels of dissolved calcium carbonate and buffering the solution against acid additions.*

Chapter 13

1) How might acid precipitation dominated by sulfuric acid increase the availability of phosphate, aside from pH effects? *Sulfate can be reduced to sulfide by microbes in anoxic conditions. The sulfide precipitates iron as pyrite. The iron then is not available to complex with phosphate in the oxidized layers above.*
2) Why are isolated chemosynthetic communities, such as those found where sulfide enters oxic cave waters or methane enters sediments, still ultimately dependent upon photosynthetic organisms? *They need O_2 from the atmosphere to oxidize the reduced compounds.*
3) When people control eutrophication, if only N is removed, cyanobacteria can dominate. Why? *Heterocystous cyanobacteria can fix N_2, and this gives them an advantage when competing with primary producers that cannot.*
4) What was the earth like before oxygenic photosynthesis and how did the sulfur cycle likely drive the redox processes of ecosystems in aquatic habitats at that time? *A complete sulfur cycle is possible in the absence of oxygen because anoxygenic photosynthesis can convert sulfide to sulfate. The sulfate can serve as an oxidant for heterotrophic microbes to respire organic carbon. Thus, in the absence of oxygen, a complete carbon cycle linked with the sulfur cycle was possible.*
5) Why are areas downstream from hyporheic zones where water reenters streams often sites of very high algal production? *Nutrients enter the zone in organic form. Heterotrophs oxidize the organic carbon and remineralize the nutrients. The nutrient-rich water flows back into the stream and stimulates primary producers.*
6) Why do sewage treatment plant operators generally want to avoid denitrification in ponds designed to settle solids? *Denitrification creates gas bubbles (with N_2) that disrupt the settling process.*
7) How might phosphate-rich water be treated with iron to remove phosphate (including O_2 concentrations and forms of iron used)? *Under oxic conditions, iron can precipitate with phosphate. It would be necessary to add low concentrations of oxidized iron at any one time to avoid losses to precipitation of iron hydroxide.*
8) Why does silicon often disappear from the epilimnion of lakes more rapidly than phosphorus or nitrogen? *Silicon does not re-dissolve rapidly once it is incorporated into diatom frustules. The frustules tend to sink before they are re-dissolved. In contrast, nitrogen and phosphorus are more rapidly remineralized in the epilimnion before they sink in the form of particles.*
9) Why is it difficult to reduce the effects of excessive phosphorus pollution in lakes when O_2 disappears from the hypolimnion? *Once the oxidized microzone is not present in the sediments, phosphate can become a free ion instead of binding with iron. Thus, phosphorus that has deposited in the sediment can diffuse out into the anoxic bottom waters of the lake and then be re-circulated to the photic zone. This stimulates algal growth.*

Chapter 14

1) Why is biomagnification worst with lipid-soluble compounds that are resistant to abiotic and biotic deactivation? *Lipid soluble compounds are difficult to excrete. The compounds cannot be broken down once they are bioaccumulated, and they bioconcentrate more because they are not broken down in the environment.*
2) Are there any habitats on earth that have not been influenced by human activities? *Perhaps some deep subsurface habitats and some Antarctic lakes that are under several km of ice (chapter 6).*
3) What political conditions have led to a world in which toxicants are routinely released into the aquatic environment before even cursory testing of their effects on organisms, including humans, has been conducted? *This is a subjective political question. It could be that the companies that make the chemicals and the industries that use the chemicals have more political clout than the general public that is exposed to the toxicants. Decisions on ways to regulate release of chemical into the environment are generally based on economics, and made in favor of groups that can afford to lobby decision-makers.*
4) Why can controls on emissions of greenhouse gasses ultimately decrease acid precipitation? *Acid precipitation is caused by industrial and automobile emissions into the atmosphere. If total automobile and industrial emissions are decreased in efforts to decrease greenhouse gas production, acid precipitation will also decrease.*
5) Why can acid precipitation lead to lower iron availability and greater phosphorus in some lakes and wetlands with anoxic sediments? *See answer to question 1 chapter 13.*
6) Why is bioremediation of metal contamination more difficult than that of contamination by organic compounds? *Organisms have evolved ways to destroy organic chemicals either as a protective measure or as a source of organic carbon. Organisms cannot destroy metals; they can only be altered to different valence.*
7) Why are microbes able to more rapidly evolve ways to inactivate toxicants than fish? *Microbes have much larger numbers of individuals that reproduce more rapidly than fish. Thus, any beneficial mutations that allow for inactivation of toxicants are more rapidly selected for and there is more variation to work with. Also, bacteria often*

have the genes for toxicant resistance on plasmids and plasmids can be transmitted among species, while fish are less likely to transfer genetic material across taxonomic lines.

8) Under what conditions may suspended solids have positive influences on aquatic ecosystems? *If suspended solids have a significant organic component, they can form the basis of ecosystem energy supply. Examples of this might be rivers and fluvial wetlands that acquire large amounts of suspended organic materials during floods.*

9) Should aquatic scientists assume a role of advocacy with regard to issues of aquatic pollution, or should their role be primarily to provide data for informed decisions to be made by managers and policy makers? *This is a personal decision. However, a scientist must remain as objective as possible to perform good science. Honesty is the best policy.*

Chapter 15

1) Can extreme habitats serve as models for early life on Earth or possible life on other planets? *Yes, because they may have similar environmental conditions, but it should be kept in mind they are only models*

2) Should efforts be made to conserve the biodiversity of unusual habitats such as hot springs? *Yes, there are unusual organisms in hotsprings that can provide valuable chemicals for biotechnological applications. These microbes may be endemic and not have a global distribution.*

3) Should companies be able to patent and take full profit from gene sequences taken from organisms collected in national parks without remuneration to the government? *This is a matter of personal opinion. However, one could argue that the biological heritage of a nation belongs to all of its people*

4) Are "extreme" habitats really extreme for organisms adapted to live in them? *This is a hard question. The organisms may not be able to compete in milder environments; however, such habitats are extreme for most organisms. Iit is difficult to think of near-boiling water as not being an extreme environment. Most organisms cannot tolerate such a habitats*

5) Why can the depth of a saline lake be highly variable from year to year and from decade to decade, and how may global climate change influence such lakes? *Depth is a function of water input from precipitation and output by evaporation. Temperature, precipitation, and wind all can vary tremendously from year to year. Global change will cause increased temperatures (evaporation) and increased precipitation, so it is difficult to predict if saline lakes will grow or shrink.*

6) Why might salt works that precipitate brines be interested in the microbiology of saline waters? *Different microbes can alter the concentrations at which specific salts precipitate, the purity of the crystals, and the order in which different chemical precipitates form. Microbes may also alter evaporation rates by controlling how much light energy is absorbed by water.*

7) How much (%) is the estimated thickness of the biosphere increased by the understanding that organisms can inhabit up to 500-m depth? *The biosphere was traditionally thought to only cover approximately the top 100 m in terrestrial systems (tallest trees), and the depth of soil. Considering microbes in deep subsurface habitats and marine sediments suggests that there are more microbial cells on earth than were previously thought. Marine systems are 1000 m deep and cover about 3/5 of he earth's surface. Assume the earth has a radius of 3,678 km, the ocean is an average of 3,795 m deep, and the ocean covers 71% of the earth's surface. This would mean that oceans plus terrestrial biosphere have a volume of about 4.62 km^3. A 500 m thick shell around the earth has about 18% of that volume.*

Chapter 16

1) Why might dissolved nutrient levels be more variable in streams than in large lakes? *Remineralization in the epilimnion of large lakes balances with uptake leading to an equilibrium nutrient concentration. Temporal variability in inputs of nutrients to streams with variations in flow, coupled with large swings in biomass may make the balance between uptake and regeneration less important.*

2) Nuisance filamentous benthic algae in the Clark Fork River, Montana, are limited by nitrogen in the summer, despite the fact that phosphorus concentrations dissolved in the water at that time are extremely low. Given that dissolved phosphorus concentrations are very high in the spring, what is a potential reason for the lack of P limitation in the summer? *The algae are able to store phosphorus through luxury consumption, leading to N-limited cells even with low external P availability.*

3) Why isn't nutrient limitation necessarily additive (e.g., why is there generally no response to additions of nonlimiting nutrients)? *If one nutrient is only slightly less limiting than the second, both must be added to get a really large response, whereas only a small response will be observed when each is added individually.*

4) What is an evolutionary argument for why nutrient competition should lead to nutrient limitation by multiple nutrients? *Organisms should evolve to utilize nutrients most efficiently in the approximate ratios in which they are*

present in the natural environment. For example, if phosphorus is often limiting, cells should evolve efficient methods of phosphorus acquisition.

5) Why may nutrient pulses be more likely to form and persist in groundwater and wetland sediments than in planktonic habitats? *Molecular diffusion predominates in many sediments, and turbulence transport is more likely for plankton.*
6) Why are large cells more likely to have high maximum rates of nutrient uptake, high half-saturation constants, and the ability for greater luxury consumption relative to small cells? *Large cells have a smaller relative surface area to volume ratio, so there are less available sites on the surface for uptake proteins. With a large internal cell volume, there is a greater possibility for significant luxury consumption.*
7) Why do many scientists think that total phosphorus concentrations are more useful indicators of nutrient supply than dissolved phosphate concentrations? *Phosphate is a highly dynamic pool. If demand is high, such as when there is an algal bloom, concentrations may be low even though supply is high (i.e. remineralization may supply the nutrient at high rates but it is consumed rapidly). Total phosphorus can represent the total P available to be converted into biomass.*
8) Why can it be misleading to use the ratio of dissolved inorganic nitrogen:dissolved phosphate, rather than the Redfield ratio of organisms, to indicate nutrient limitation? *Think about the answer to the previous question, but then consider that two dynamic pools are being considered for the dissolved inorganic forms.*

Chapter 17

1) Why is a common classification system for trophic state useful for aquatic scientists, even if it is mainly a way to classify a continuous gradient of habitat types? *It makes comparison of ecosystems in different geographical regions more consistent. For example, a lake that is considered oligotrophic in an agricultural area may be considered very productive when compared to pristine mountain lakes.*
2) Why is the notion of slow, constant movement toward a more eutrophic state in natural systems probably naive? *Many lakes have a long geological history. The actual period of time that they are shallow and eutrophic may be limited relative to the time that they exist.*
3) Why does a lake manager need to be aware of the variance associated with loading equations when making management recommendations? *Economic decisions need to be made with some idea of the probability of failure. If millions of dollars are spent on nutrient control and there is no apparent decrease in the symptoms of eutrophication, the credibility of the manager will be in question for future decisions and money will have been wasted.*
4) Why might some ecoregions have lakes that naturally have blooms of heterocystous cyanobacteria? *Phosphorus-rich areas will tend toward nitrogen limitation.*
5) Why would addition of Fe^{3+} to remove PO_4^{3-} from the epilimnion cause only temporary relief from eutrophication when the hypolimnion is anoxic? *The $FePO_4$ will sink and re-dissociate into Fe^{2+} and PO_4^{3-} and be mixed through the lake in fall overturn.*
6) Why is the relationship between total P and planktonic chlorophyll in lakes stronger (less variable) than the relationship between total P in streams and benthic chlorophyll? *A significant proportion of total P in lakes may actually be algal biomass, and thus be part of the same cells that contain the chlorophyll. In streams, water column nutrients are not the same as benthic biomass. In addition, factors such as floods and grazing may be more important and variable over space and time in rivers and streams than in lakes.*
7) Why might eutrophication of wetlands make insectivorous plants such as sundew and Venus flytrap, less competitive? *Insectivorous plants probably rely upon their prey for nitrogen, and appear to be common in N-limited wetlands. Eutrophication may release the plant community from N-limitation and decrease the relative competitive ability of insectivorous plants.*
8) Some people have treated eutrophication problems in lakes by diluting them with river flow. What conditions are necessary for this solution to work? *Plenty of low nutrient water with an adequate discharge to dilute nutrients in the lakes significantly.*

Chapter 18

1) Why do obligate mutualisms appear to be a more important type of interaction in coral reefs than in the benthos of lakes and streams? *Coral reefs probably have a longer co-evolutionary history and more diversity to work with that can result in highly specialized interactions. Lakes and streams are more ephemeral habitats over geological time.*
2) How might shredders and scrapers alter microbial activity on leaves in streams? *Macroinvertebrates that shred or scrape leaves may increase the surface area for microbes that decompose detritus.*
3) Is it possible that interactions among organisms can change over time or with changes in biotic conditions? *Yes, for example a hydra may loose its algal endosymbionts if there is lots of food to ingest and little light. Also, fish and*

invertebrates can change their strategies as they get bigger. For example, a fish may be planktivorous when young and a piscivore when older.

4) Why is it less likely that individual diatom species found in periphyton assemblages would produce chemicals to deter scrapers than would macrophytes? *A diatom in a periphyton assemblage is only one species among many. The toxin would be diluted and thus not likely to be effective. A macrophyte is an individual, and can have concentrated toxins that stop small herbivores before the entire plant is consumed.*
5) Planktonic bacterial populations may respond in a complex manner to temperature. Can you predict if lower growth or decreases in predation rates related to increased viscosity should be more important controls of biomass? *This is very difficult to predict without more data. Specific data on growth rates versus temperature and effectiveness of bactivores is needed before predictions of temperature effects can be made.*
6) What kind of predator was the precursor to eukaryotic cells (before chloroplasts and mitochondria)? *One that engulfed whole cells and maybe one that had the strategy of acquiring endosymbionts, such as dinoflagellates do today.*
7) Why is chemical sensing of microbial prey so important but visual identification more likely with larger scale prey? *Eyes require multi-cellular apparatus and are not likely effective on the scales of microbes. Sensing chemical signatures on the surface of particles can identify if a food source is nutritionally profitable or edible. Also, plumes of excreted chemicals are more stable at microbial scales where chemical dispersion is dominated by molecular diffusion.*
8) Under what conditions might an algal species exhibit photophobic response? Why may an obligate anaerobe be photophobic? *An alga may avoid levels of light that would be photoinhibitory. An anaerobe avoids regions where organisms can photosynthesize and produce O_2 that may be toxic.*
9) Adhesion to collecting appendages may be an important mode of collection of bacterial prey. Why are viscous forces and Reynolds number important to consider in such cases? *The ability of a particle to make contact with a solid surface and then adhere depends in part upon Reynolds number. If particles are small enough, filters will not work well as a collection strategy, thus adhesion may be the only way to collect such particles for larger organisms.*
10) Why are filter feeders found in the water column of lakes but mainly on the benthos (not as much in the water column) of rivers? *Turbulence may destroy them. It is more efficient for an organism to filter feed in a stream by attaching to the bottom and allowing water movement to bring particles in. Net spinning caddis fly larvae and mussels are examples of this strategy in rivers.*

Chapter 19

1) If a predator is consuming prey at a rate lower than the rate at which the prey is able to replace itself, can the effect of predation be considered significant even if the prey population is increasing? *Yes, because in the absence of the predator the prey would be even more successful.*
2) Why can increasing turbidity of large rivers cause shifts in types in types of predators that are successful? *Sight-feeding predators are less likely to dominate in turbid conditions. Also turbid rivers are likely to have mud or silt bottoms, and have different invertebrate assemblages present as prey.*
3) Why might it be more effective to control algal blooms by biomanipulation with removal of all fish than by imposing fishing regulations to increase the number of piscivorous fish? *Large fish are required to control zooplanktivorous fish, and anglers prefer to remove large fish. Anglers are irrelevant if there are no fish.*
4) Why are brightly colored organisms less common in freshwaters than in benthic marine systems? *More time for evolution means more time for sexual selection and development of warning coloration in toxic species.*
5) What single cosmopolitan species is the top predator in more freshwater systems across the world than any other species? *Homo sapiens.*
6) Why are chemical cues to prey easier to follow in streams and benthic habitats than in pelagic habitats? *In unidirectional flow, the plume can be followed upstream in a predictable direction.*
7) How do selective pressures for streamlining of fishes conflict with limitations on gape width? *It is mechanically difficult to be well streamlined and have a really large mouth.*
8) Are trophic levels a valid concept in most freshwater habitats? *For some organisms they are, but others, such as stream invertebrates that are omnivorous, classification by trophic levels may be too simplistic of an approach to capture natural patterns.*

Chapter 20

1) How can disturbance in a habitat act as an agent of natural selection? *Disturbance can select for species that are "r selected", those able to recolonize disturbed habitats. Competitive dominants in stable habitats may not be able to maintain dominance in disturbed habitats.*
2) Are indirect interactions so strong and numerous that they complicate predicting the effects of interactions within an ecological community? *Frankly we do not know. This is a very important question for ecologists.*
3) How predictable are successional trajectories (i.e., can sequences of species colonization be predicted, or just general patterns)? *If the natural history of organisms is well known in an area, predicting the trajectory of succession is possible. However, chance plays a large part in the process, so predicting that a specific organism will become established at a known location and a particular time is difficult, if not impossible.*
4) How might understanding species interactions be important for predicting the effect of introduced species? *If the way a species interacts with others is well described, it may be possible to predict how it invades new ecosystems. Also, control measures such as introduction of biocontrols requires an understanding of how the biocontrol organism will interact with the native species.*
5) How can disturbance make competition less intense? *It can reduce numbers of the competitive dominant.*
6) If a species is a keystone species, should greater attention be paid to conservation of that species than others in a habitat? *Probably, since it has an inordinate effect on other species in the habitat and may be crucial to community structure.*

Chapter 21

1) Do lakes and streams commonly contain unused niches that can be exploited by fisheries managers wishing to improve sport fisheries? *In some cases this probably is true, but the history of introduction of fish is full of examples where there are unintended consequences of the introduction that include competition with native species.*
2) Why are unregulated fisheries overexploited? *People tend to take whatever they can get from their environment. See an environmental issues book for the "Tragedy of the Commons".*
3) How might fisheries management for sport fisheries lower diversity of native fish populations? *Selecting for large piscivores may hurt populations of small native fishes. However, sometimes maintaining habitat and water quality for a strong sports fishery may enhance native fish populations.*
4) Do the indices used by fisheries managers, such as RSD, have any ecological relevance? *The indices simply reflect population structure and that has ecological relevance. However, the size categories are often arbitrary and have no ecological basis.*
5) Why are herbivorous and detritivorous fishes more often utilized for food in Asia than in North America? *Such species can be more productive per unit area because they feed lower on the food chain. Also, their food is cheaper which matters when people have less money.*
6) Why should genetic diversity of fish stocks be an important aspect of aquaculture? *Disease resistance and avoiding inbreeding depression both require maintenance of genetic diversity.*

Chapter 22

1. Why are wetland ecosystems so much more productive than streams? *Disturbance is low, nutrients and water are often plentiful, and the sediments allow establishment of emergent plants that are very efficient at intercepting light and less likely to be limited by CO_2 than submerged plants.*
2. Why do wetland ecosystems store a greater amount of carbon than lakes or streams? *Wetlands often have well-established anoxic zones and fermentation reactions lower pH. These factors lead to decreased decomposition. High rates of detrital input and lack of shredders may also contribute to carbon deposition.*
3. Can a lake ecosystem be adequately described with a two-compartment model, one for the pelagic zone and another for the limnetic zone? *It depends on why you need the model. If the hypolimnion is anoxic, at least one more compartment would be required. Sediments should usually be considered separately as well.*
4. Do whole communities evolve over time to optimally exploit ecosystems? *Probably not. Evolution of individual species acts to create a very efficient community that appears to optimally exploit resources available in ecosystems. There is not a compelling argument, or direct evidence for coevolution of large assemblages of species.*

5. If global warming increased the number of freshwater marshes by converting northern peatlands into marshes, what would happen to methane production? *Methane production would increase, and have a positive feedback on the greenhouse cycle.*
6. How well does an equilibrium model represent stream ecosystems relative to lake and groundwater ecosystems? *Streams are farthest from equilibrium, so a equilibrium model would be least realistic in streams.*
7. Should ecosystems be preserved in addition to endangered species? *Yes.*
8. Some people refer to "biotic integrity" and "ecosystem health" in the context of conservation of the environment. What do you think these terms mean and how should they be defined? *Biotic integrity generally refers to the normal biological diversity in the absence of large anthropogenic impacts. Ecosystem health generally refers to normal ecosystem processing rates such as photosynthesis, trophic transfer, denitrification etc.*
9. How can some ecosystems have a higher biomass of predators than primary consumers? *Biomass is not the same as production. Primary consumers can have high production and provide ample food for a larger predator biomass with lower total production.*