Macroinvertebrates and Stream Quality Lesson Plan (pre-field trip)

Grade level(s): 9

Standards Met:

4.2.10.C.
Explain the relationship between water quality and the diversity of life in a freshwater ecosystem.

Explain how limiting factors affect the growth and reproduction of freshwater organisms.

Objectives: Students will be able to use a biotic index to identify macroinvertebrates in a stream. Students will be able to predict overall health of a stream using macroinvertebrate identifications. Students will identify and explain additional factors that impact biodiversity and overall health of a stream.

Materials: Organism cards for pond A and pond B, response sheet, fact sheets, biotic index, dichotomous key, leaf packs (optional)

Procedures:
Engage: "Question of the day:" What observations would allow you to predict the overall health of a freshwater system?

Explore: Which pond is healthier activity- students will be given 2 "ponds" with macroinvertebrates (Ponds will be basins with cut out pictures of macroinvertebrates). Using their own background knowledge, they must predict which pond is healthier and explain why.

Explain: Students will be introduced to pollution tolerance and identification of macroinvertebrates. Students will then use a biotic index to identify each organism in both ponds and their pollution tolerances. They will use these numbers and the formula provided to determine water quality. They will re-evaluate their original prediction and explain their reasoning.

-- At this time the teacher may also introduce leaf packs and technique for field use.

Elaborate: The students will read several articles found on the following website:
http://sites.allegheny.edu/creekconnections/classroom-resources/water-chemistry-parameters-fact-sheets-instructions/

They will click on the dissolved oxygen fact sheet, nitrates fact sheet, phosphorus fact sheet, pH fact sheet, and turbidity fact sheet. They will read through each fact sheet and respond to questions about each factor.

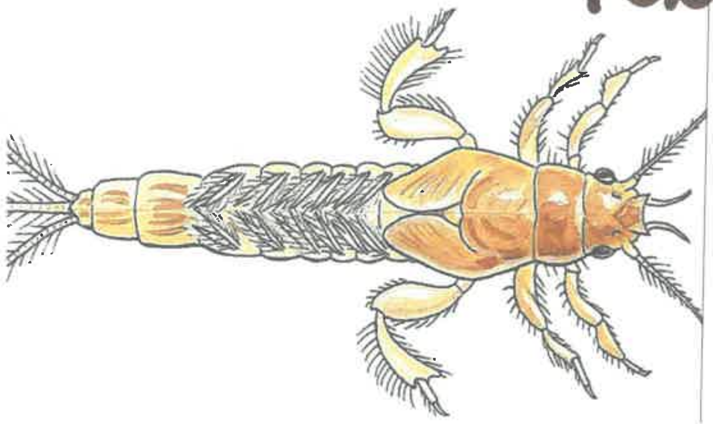
Evaluate: Writing prompt: Students will write a paragraph identifying 3 factors that can be used as an indicator of water quality in an ecosystem and explaining the impact of each on biodiversity and stream quality.

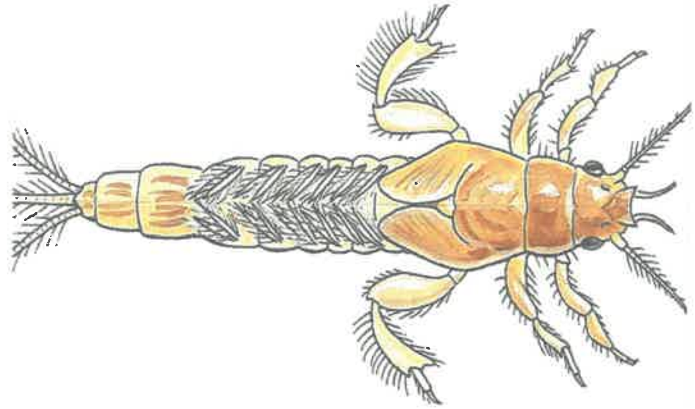
Extension activity- Students will practice their identification abilities through macroinvertebrate BINGO. Students will choose from the list of macroinvertebrates and construct a bingo card with their common names. To play, a picture will be shown on the board of a given macroinvertebrate. If a student has the matching name, they will place a chip over it on their card. Once a student has a horizontal, vertical, or diagonal line filled, they will yell "BINGO!"

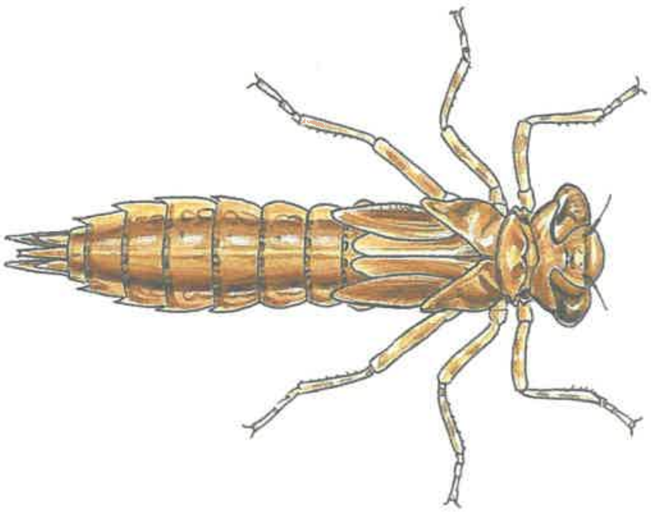
Anticipated Problems & Adaptations:
Students may struggle identifying organisms. Practice on using a dichotomous key may be necessary.

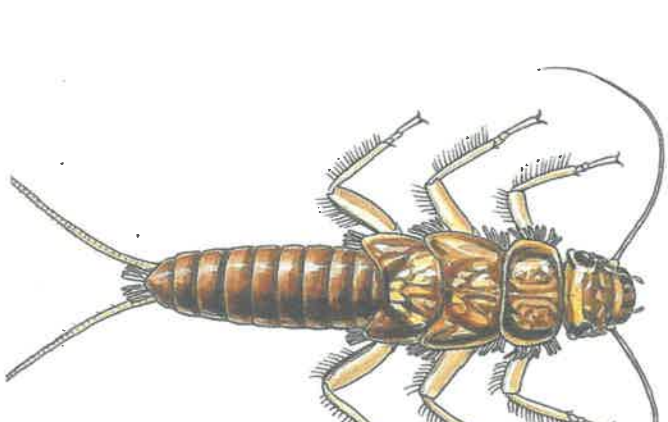
Resources:
http://sites.allegheny.edu/creekconnections/classroom-resources/macroinvertebrate-identification-game/
http://sites.allegheny.edu/creekconnections/classroom-resources/water-chemistry-parameters-fact-sheets-instructions/

POND A









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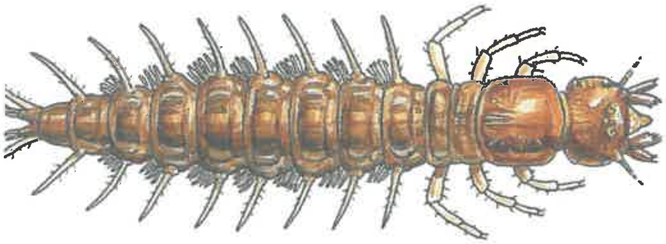

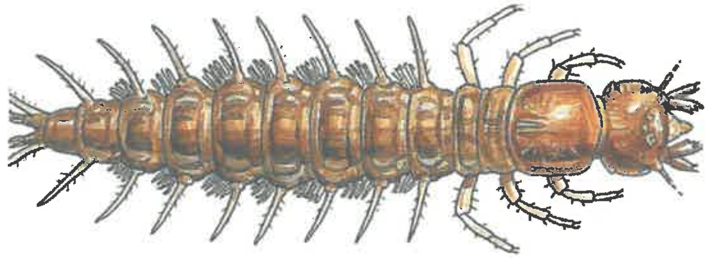

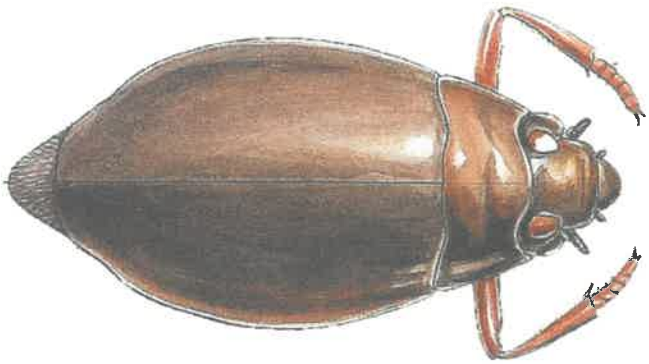

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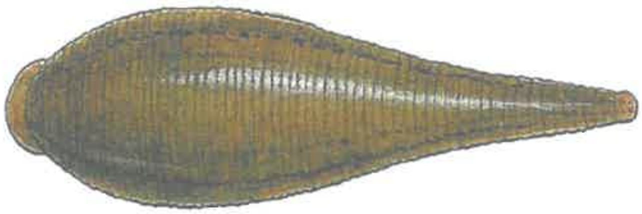
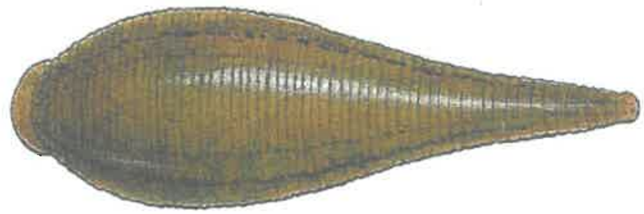

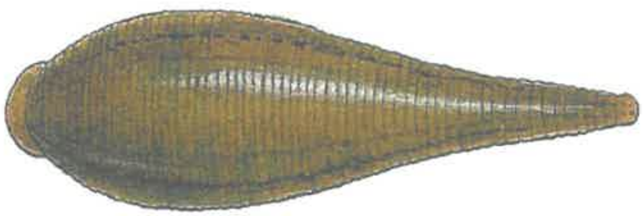
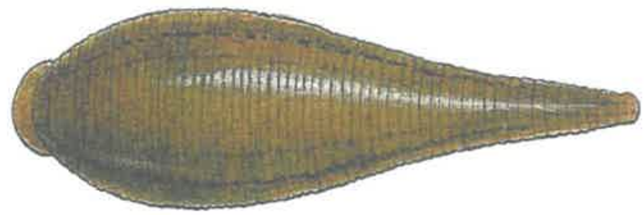


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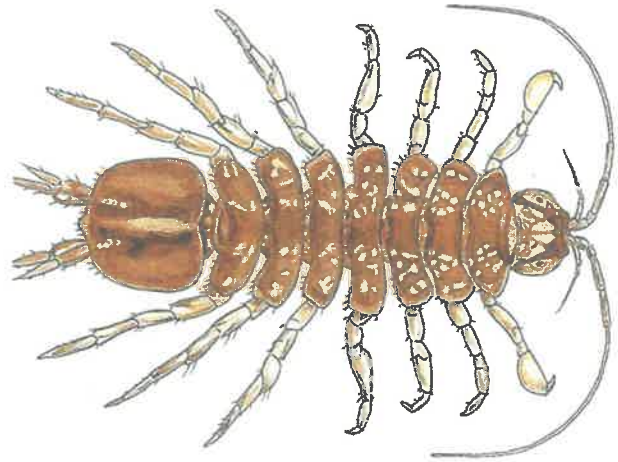

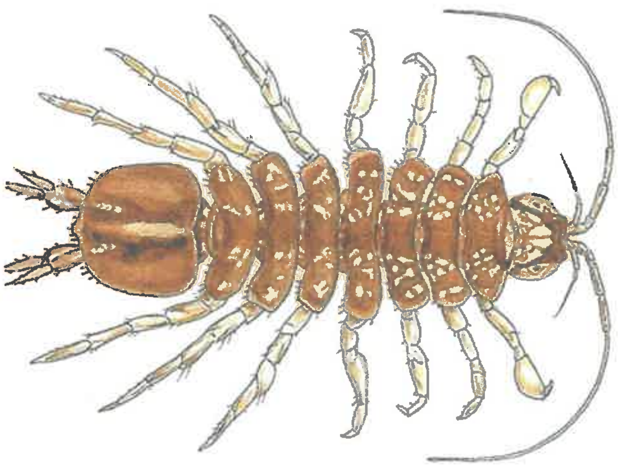

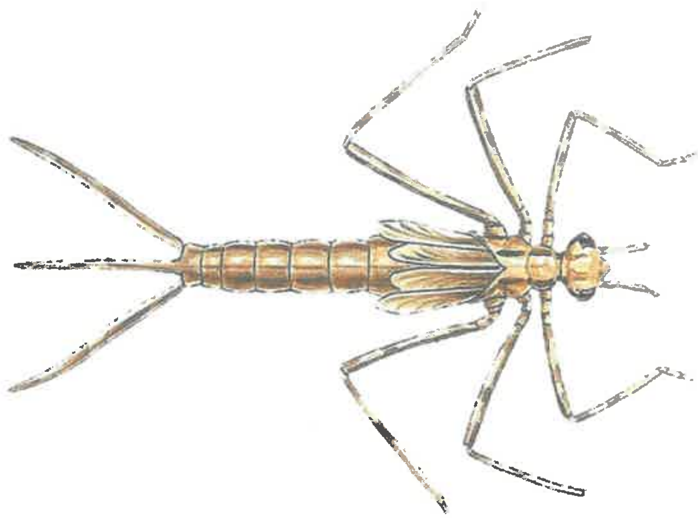

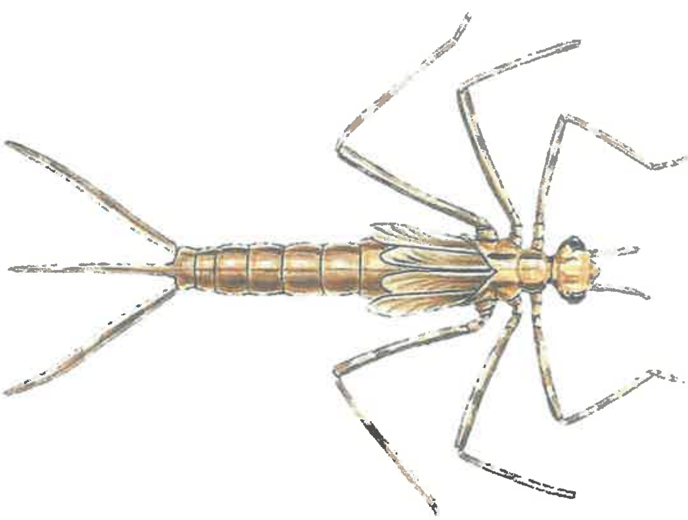

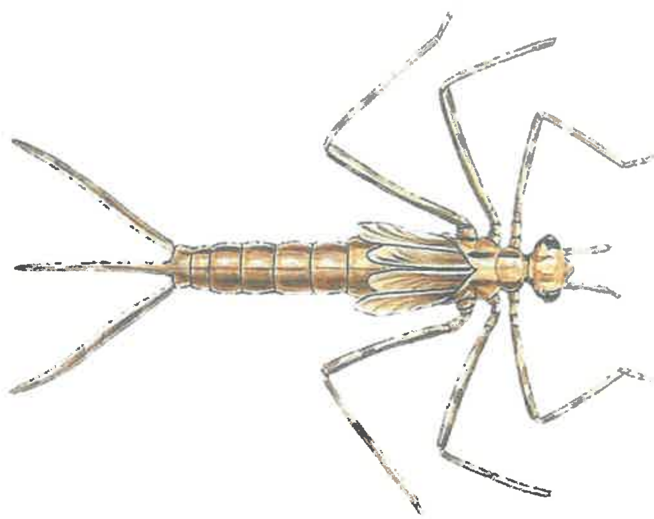

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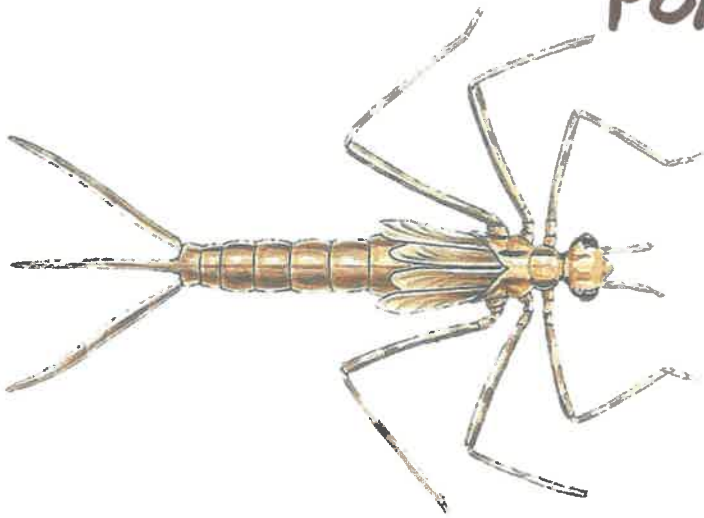
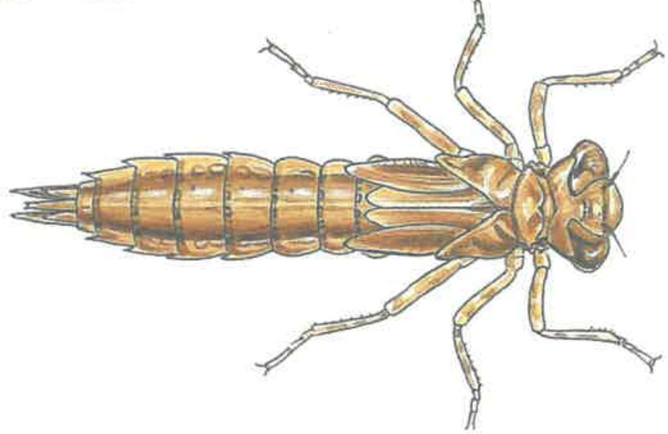
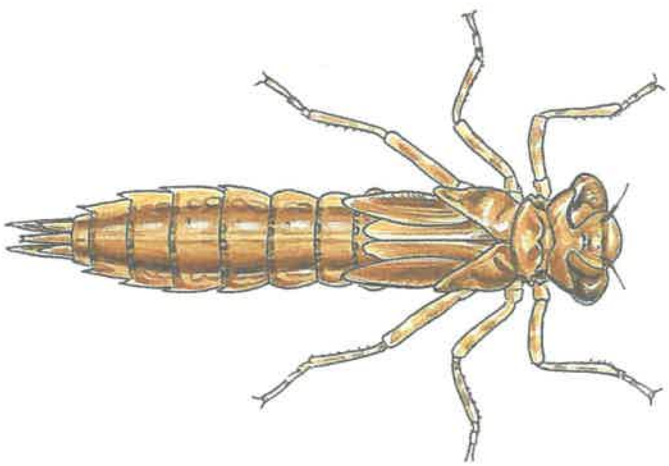
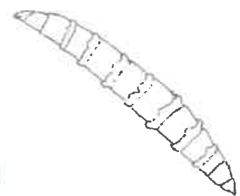










Identification Guide to Freshwater Macroinvertebrates


STROUD™
WATER RESEARCH CENTER


970 Spencer Road
Avondale, Pennsylvania 19311

Macroinvertebrate images prepared for
Stroud Water Research Center by Mr. Kevin Gill


Major Characteristics of Aquatic Larvae

GLOSSARY

Abdomen: posterior body segment of insect

Filaments: hair-like structures

Jointed leg: true legs, legs capable of bending

Lateral: at the side

Portable case: structure made of leaves, twigs, or sand that some caddisfly larvae carry with them

Posterior: tail end of the body

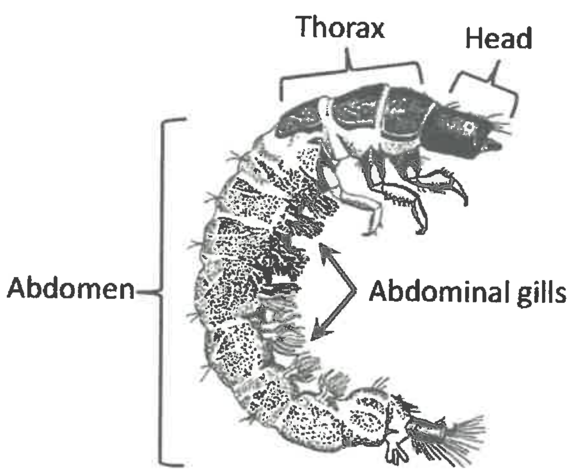
Prolegs: short, stumpy leg-like structures (not jointed)

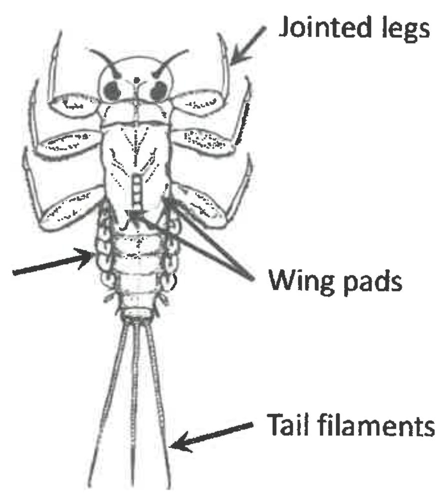
Protrusion: part of the body that sticks out

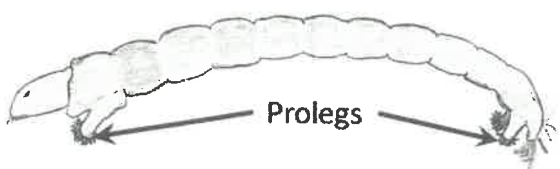
Segment: a section of body

Ventral: underside

Wing pads: developing wings, often W in shape







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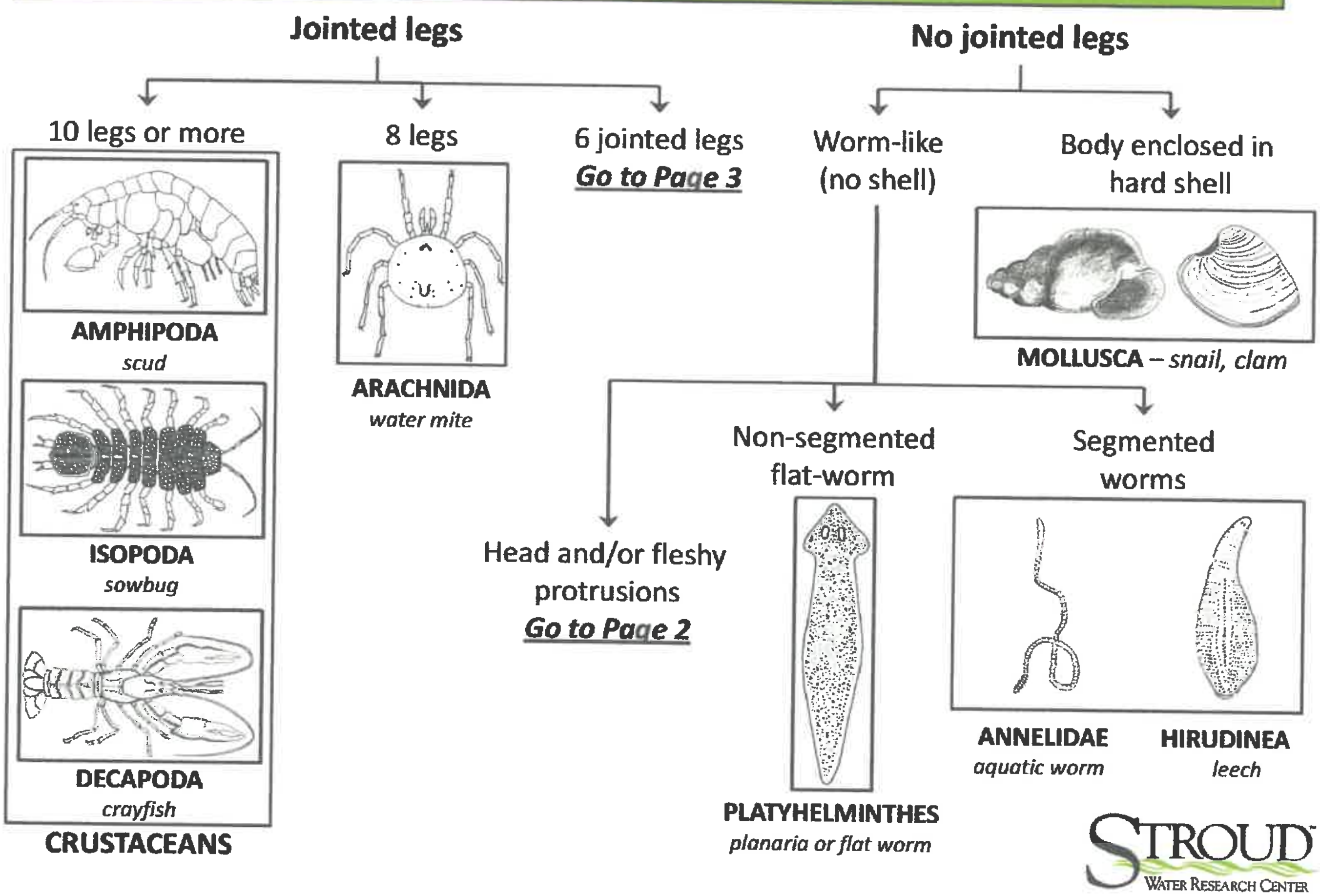
Identification Guide to Freshwater Macroinvertebrates



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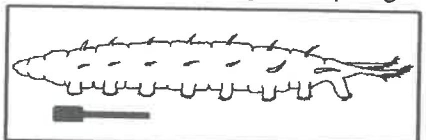
Worm-like with distinct head or fleshy protrusion

DIPTERA – *true flies*

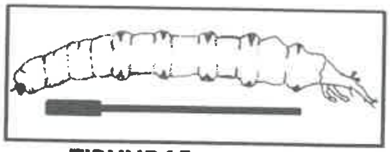
Head small, often hidden from view

8 pairs of prolegs; posterior with 2 pointed protrusions longer than prolegs



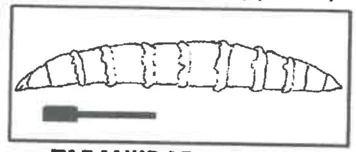
ATHERICIDAE – *water snipe flies*

Fleshy protrusions at posterior end



TIPULIDAE – *crane flies*

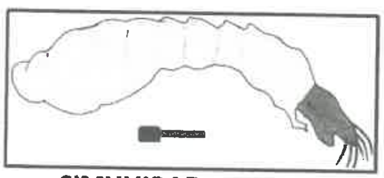
Head capsule retractile, first 7 abdominal segments ringed by fleshy pseudopods



TABANIIDAE – *horse flies*

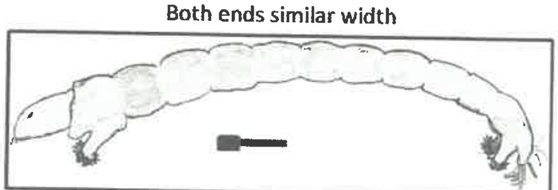
Distinct head

One end wider than the other



SIMULIIDAE – *black flies*

Both ends similar width



CHIRONOMIDAE – *midges*

Approximate size range

Minimum Maximum

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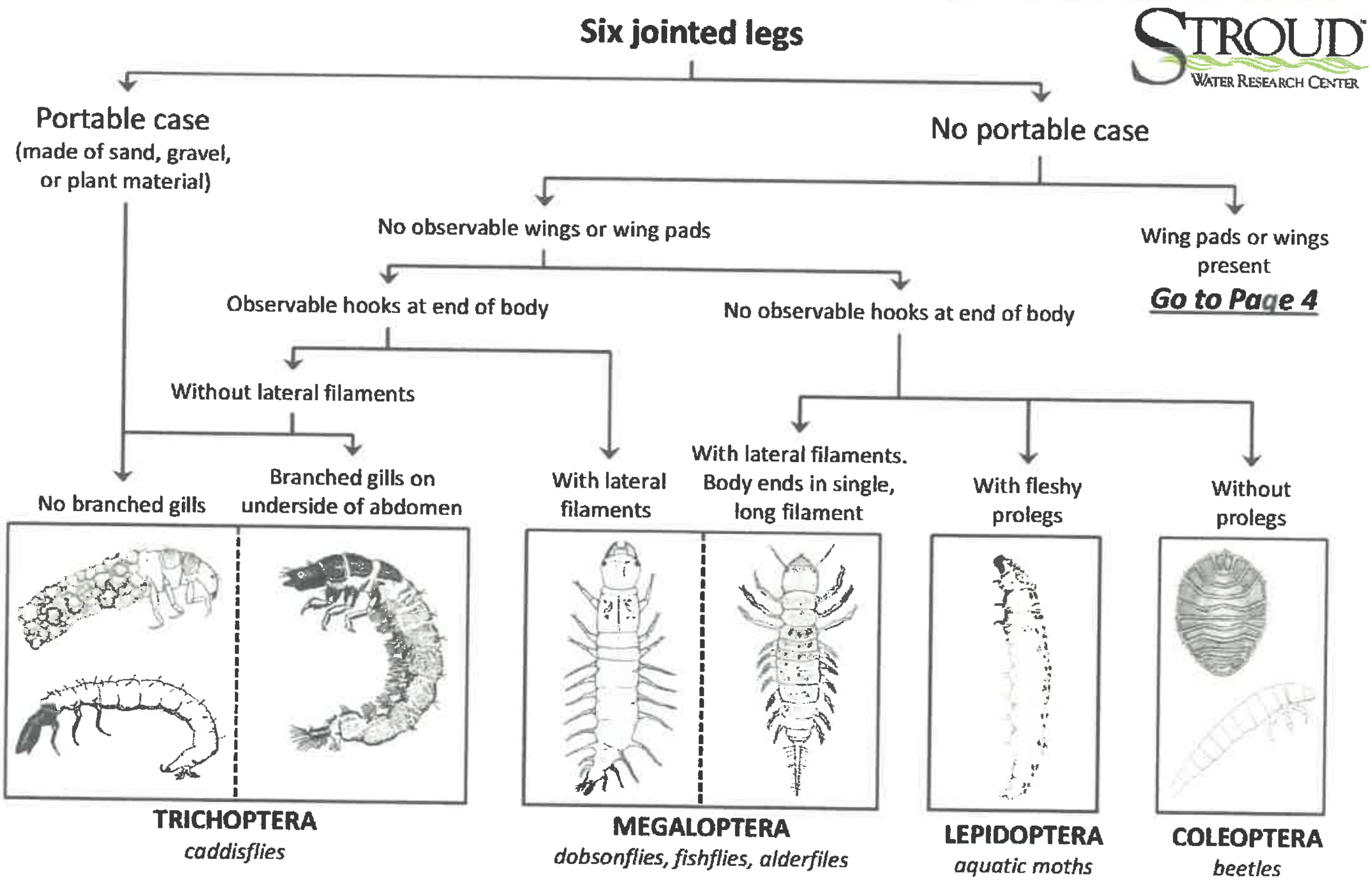

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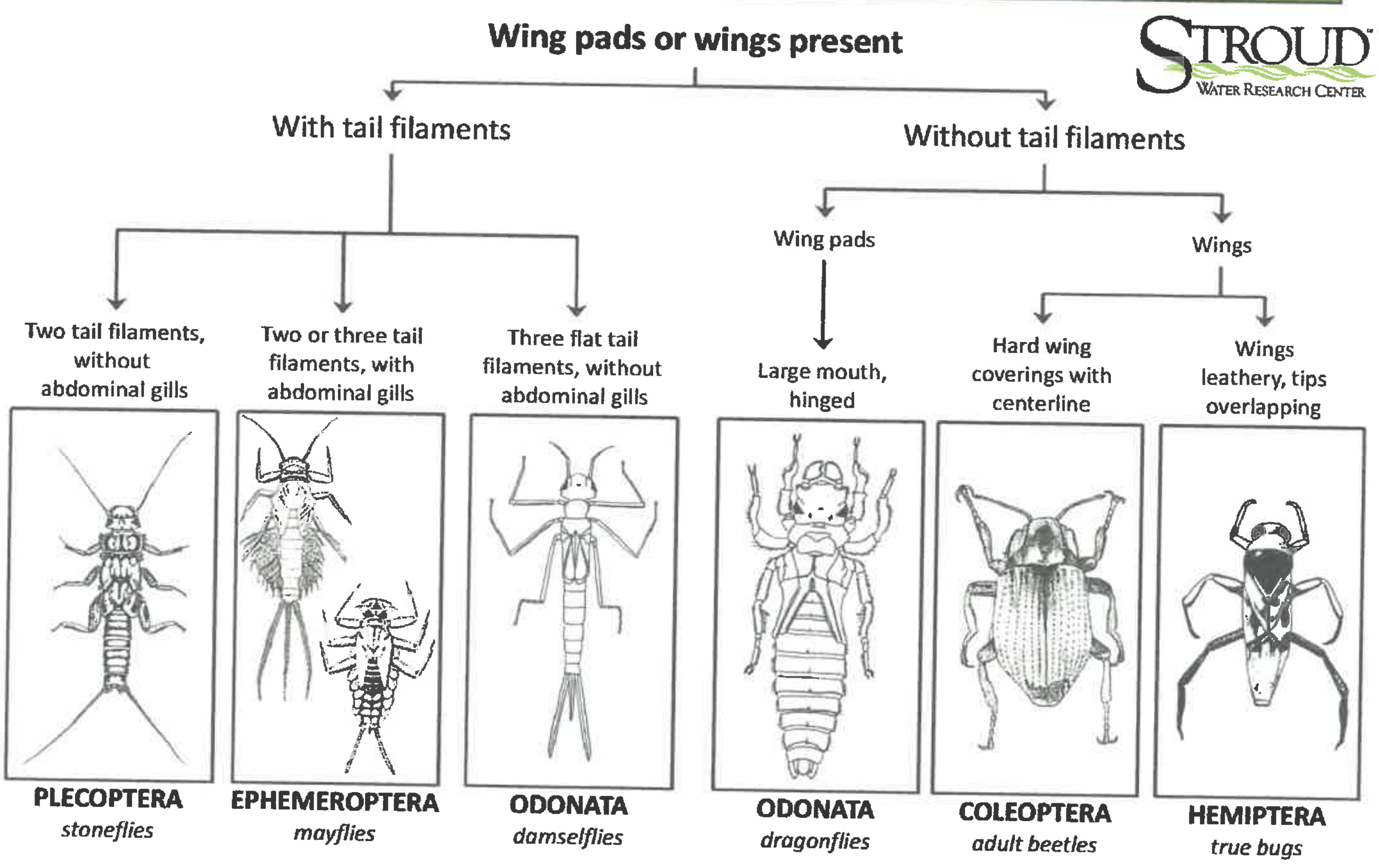


DISSOLVED OXYGEN FACT SHEET

Definition: Microscopic oxygen (O_2) molecules that are mixed within water… dissolved oxygen is found in the spaces between water (H_2O) molecules.

Background:
- Aquatic animals and aerobic bacteria need O_2 for respiration…*without* dissolved oxygen, fish would drown!
- Presence of dissolved oxygen is a positive sign, while its absence is a signal of severe pollution.

Physical Influences:
- Temperature - dissolved O_2 is normally greatest during the winter because cold water can hold more O_2…(as temperatures drop, water molecules are spaced farther apart).
- Wet weather or melting snow increases flow, which results in greater mixing of atmospheric oxygen.

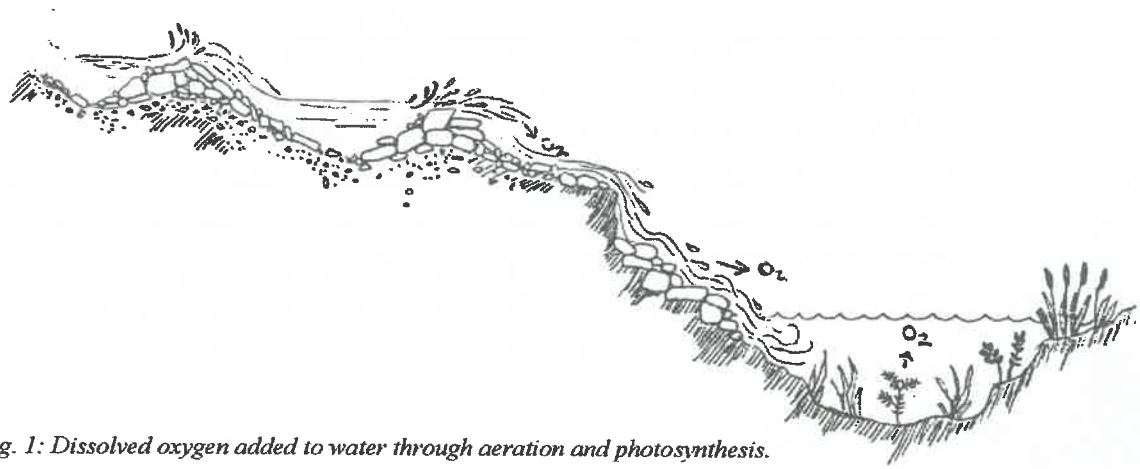


Fig. 1: Dissolved oxygen added to water through aeration and photosynthesis.

Aquatic Life Influences
- Algae and aquatic plants deliver O_2 to water through photosynthesis.
- Respiration/decomposition removes dissolved O_2.
- During growing seasons, dissolved O_2 is highest in early afternoon when aquatic photosynthesis is maximal.

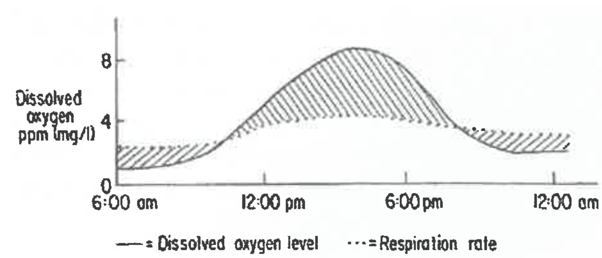
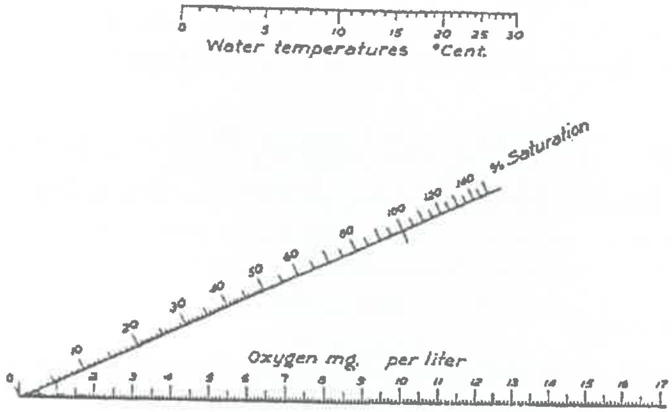


Fig. 2: Dissolved oxygen as it relates to plant respiration (source: Caduto, 1985 – Pond and Brook*)*

Percent Saturation:

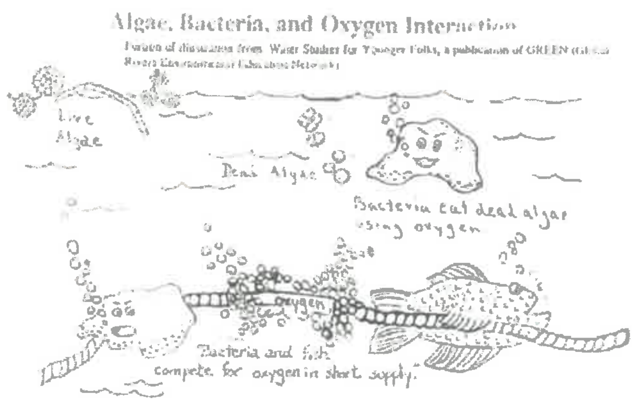
- The percentage of oxygen available in the water.

To determine percent saturation:
Multiply your DO level (mg/L) by an atmospheric pressure correction factor
Elev. 542-1094 = .98 factor
Elev. 1094-1688 = .96 factor
Find this corrected DO level on the bottom horizontal line and draw a straight line to connect to the water temperature (top line).



Environmental Impacts:

- Temperature changes - any actions that change the temperature of the stream affect dissolved oxygen.
- Nutrient additions – from fertilizers encourage excessive plant growth (algal blooms), which eventually die and need to be decomposed by aerobic (oxygen using) bacteria. DO levels drop. This is **eutrophication**.
- Organic waste additions (anything once part of a living plant or animal) enter waterways through death of aquatic plants, sewage, urban & agricultural runoff, and discharge of food processing plants. Aerobic bacteria also consume organic waste, depleting oxygen levels. This use of oxygen is called **biological oxygen demand**.
- Turbulent water released from a dam can have such a high DO level that it can be toxic to organisms.



Water Quality:

- The U.S. EPA considers healthy water to have 5 mg/L dissolved oxygen; below 4 mg/L water quality is considered poor.

Links:

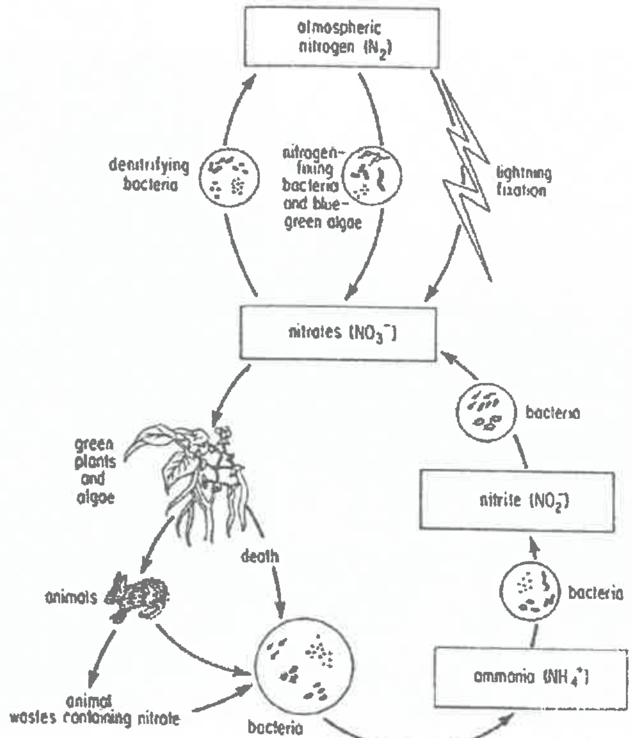
1. *Depicts* the effects that decreasing levels of DO have on wildlife
http://waterontheweb.org/under/waterquality/oxygen.html
2. *Dissolved Oxygen*~describes why dissolved oxygen is important
http://www.epa.gov/volunteer/stream/vms52.html
3. *Dissolved Oxygen in Lake Erie*~Shows DO levels since 1970
http://www.epa.gov/glnpo/lakeerie/dostory.html

NITRATES (NO_3) FACT SHEET

Definition: An important nutrient for plants and animals used in the building of proteins, DNA, and RNA. It is found naturally in waterways but, excessive amounts cause problems.

Background:

- Nitrogen is a very common element found in many forms throughout the environment (occurs in waters as nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3).
- Bacteria and blue-green algae convert atmospheric N_2 into forms (ammonia & nitrate), which plants can absorb through their roots. This process is called **nitrogen fixation**.
- Aquatic animals obtain nitrogen by either consuming aquatic plants or consuming those animals that consume the plants.
- Nitrates can be returned to the soil from animal urine, feces, carcass decay and plant decay.



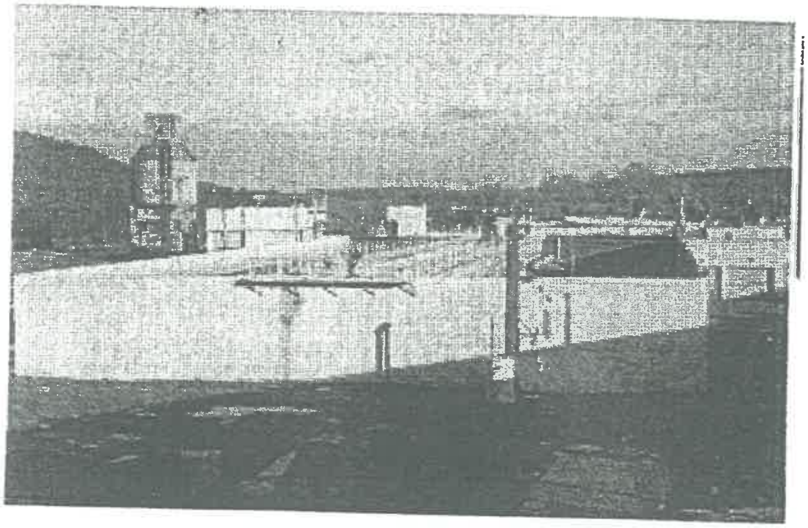
Caduto, 1984

FIGURE 2–6: The nitrogen cycle.

Environmental Consequences:

- Oversupply of nitrates and ammonia leads to **eutrophication**. High levels of nitrates or phosphates stimulate algae and aquatic plant growth. Aerobic bacteria populations then increase because of the large amounts of organic matter now available in the water. The resulting elevated bacteria populations deplete much of the dissolved oxygen found in the water.
- Excessive algal growth creates a soupy green stream, which can be visually displeasing.

- Excessive aquatic weed (macrophytes) growth can make boating and swimming difficult.
- Humans add large quantities of nitrates into waterways through sewage (treatment plants and septic tanks), fertilizers (from farms and lawns), nutrient rich runoff from cattle feedlots, dairies, and barnyards and nutrient rich soils washed in from a deforested area.



Sewage is a major source of waterway nitrates. It can enter from outdated wastewater treatment plants, faulty septic tanks, and illegal sewage connections. There is a new Meadville Wastewater Treatment plant (left) that has eliminated releasing untreated sewage to French Creek. Photo source for above: Cunningham and Saigo, 1999.

- Nitrates can produce a serious condition in fish called "brown blood disease."
- Nitrates also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. This destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age.

Water Quality:
- Unpolluted waters have a Nitrate level of below 1 mg/L.

Links:

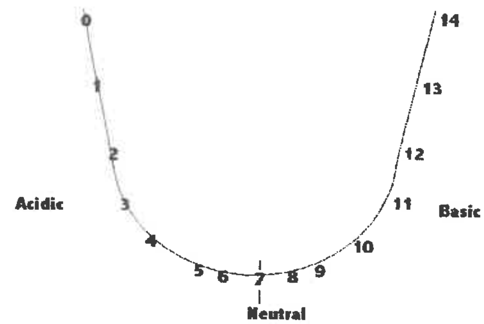
1. *NO_3* ~ General overview of Nitrates in streams
http://www.heinzctr.org/ecosystems/forest/nitr_strms.shtml
2. *Testing for Nitrates* ~ Describes what nitrates are, and how to test for them in water
http://www.epa.gov/volunteer/stream/vms57.html

pH FACT SHEET

Definition: A measurement of hydrogen ion concentration (H+) in liquids and other substances. The amount of H+ can determine whether the substance is acidic or basic, (alkaline).

Background:

- Water contains both H^+ (hydrogen) and OH^- (hydroxyl) ions.
- Pure distilled water has an equal number of hydrogen and hydroxyl ions… making the water neutral (pH of 7).
- More hydrogen than hydroxyl ions results in an acidic solution, (pH <7).
- More hydroxyl than hydrogen ions results in a basic solution, (pH >7).
- pH is expressed on a Log10 scale from 1-14, thus a pH of 6 is *10 times* more acidic than pH of 7.
- Natural rain has pH of about 5.6, ($CO_2 + H_2O$ forms carbonic acid, which breaks off a H+ and makes rain acidic).
- Organic acids in upper soil layer can lower pH by producing extra H+.
- Calcium carbonate rocks and soils ($CaCO_3$), can buffer changes in pH.
- Photosynthesis removes CO_2, (and eventually carbonic acid) making water more basic.
- Respiration/decomposition adds CO_2 (and eventually carbonic acid) making water more acidic.



carbon dioxide + water + **solar energy** ⇒ glucose + oxygen

$6\,CO_2 + 6\,H_2O$ + **solar energy** ⇒ $C_6H_{12}O_6 + 6\,O_2$

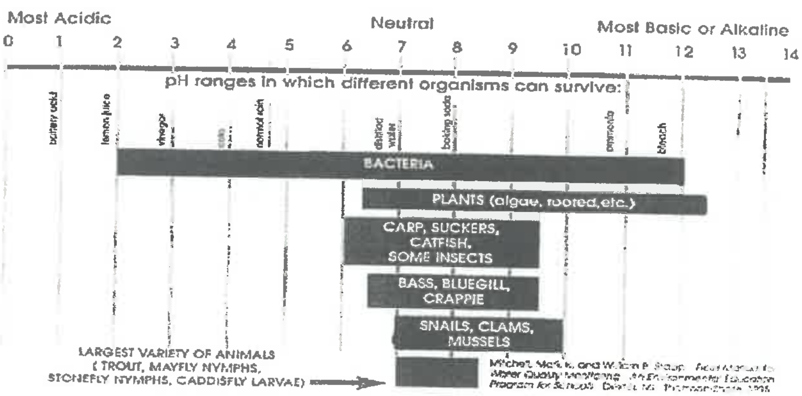
glucose + oxygen ⇒ carbon dioxide + water + **energy**

$C_6H_{12}O_6 + 6\,O_2 \Rightarrow 6\,CO_2 + 6\,H_2O$ + **energy**

- *High pH* prevails in summer when waterways are heavily influenced by groundwater flow and buffered by limestone soils and more photosynthesis occurs.
- *Low pH* prevails in late winter and spring when snow melts and precipitation rapidly enters waterways (without contact with calcium carbonate rocks), there is less buffered groundwater influence, and photosynthesis is not occurring.

Environmental Impacts

- Effects of acid rain are worse in those regions that:
  - Are downwind of industrial areas
  - Do not contain calcium carbonate in rocks and soils to reduce acidity.
- Primary cause of acid rain is from nitrogen oxides (NO_x) and sulfur dioxide (SO_2), from automobile and coal-fired power plant emissions, which transform into nitric & sulfuric acid.
- Northeast USA typically receives acidic rain of pH 4.5 or lower.
- Resulting acidic rain precipitates to the ground, rendering waterways too acidic to support aquatic life.
- Average pH of natural creek water in Pennsylvania is between 6.5 and 8.5, except in acid mine drainage streams.
- Most organisms are adapted to live within a specific range of pH, thus, even a slight change may be fatal.



Source: Cuyahoga Valley Environmental Education Center, Peninsula, OH. Student Discovery Book, 5/97 Version

Fig. 4: pH ranges in which different organisms can survive
Source: Cuyahoga Valley Environmental Education Center, *Student of Pennsylvania Discovery Book* *5/97 version. Peninsula, OH.*

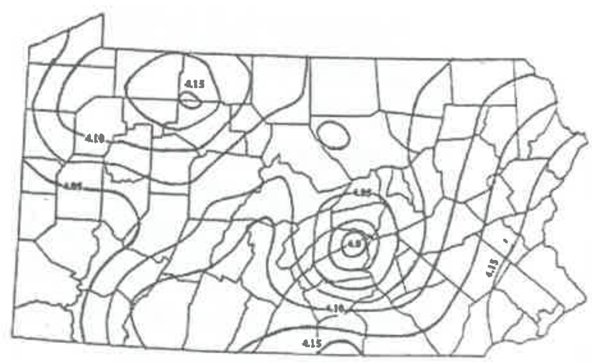


Fig. 5: pH of rain in Pennsylvania
Based on: Cuff, 1989. Atlas 1997.

- Acid mine drainage, from coal mining and other resource extraction, contains sulfuric acid (H_2SO_4) which can break off an extra H+.
- Acidic water (low pH) releases metals, which can harm aquatic life.

Water Quality:

- Natural waters should have a pH between 5-8.5.
- EPA's required pH levels for drinking water is 6.5-8.5.

Links:

1. *Monitoring Water Quality* ~ defines pH and importance to water quality
http://www.epa.gov/volunteer/stream/vms54.html
http://www.fisheries.nsw.gov.au/aquaculture/extension_services2/water_quality_monitoring_-_ph

PHOSPHORUS FACT SHEET

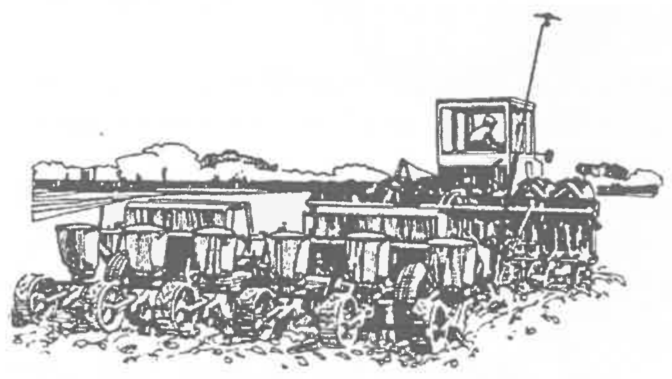
Definition: An essential nutrient that is fundamental to the development of nucleic acids and cell membranes of plants and animals.

Background:

- Phosphorus occurs in several forms:
  - *organic phosphates* from plant-animal matter, waste
  - *inorganic (also called orthophosphate, free phosphates, reactive phosphates)* naturally occur and bind to soil particles.
- It is often a limiting nutrient for freshwater phytoplankton & plants.
- It naturally enters surface waters from organic decay & soil weathering.

Environmental Impacts:

- Excess Phosphorus comes from sewage treatment plants, fertilizer runoff, farm manure piles, detergents and phosphoric acid industrial cleaners.



FERTILIZING

Fig. 1: One of the major contributors to high levels of phosphates in waterways today is from fertilizers. Rainfall carries fertilizers into nearby creeks and lakes, therefore unnaturally increasing nutrient levels. Too much phosphate can help cause algal blooms and other excessive plant growth.

- Excessive phosphate levels cause an overabundance of plant growth – algae and aquatic weeds (macrophytes).
- When resulting algal blooms die, their decomposition from aerobic bacteria removes dissolved oxygen from water (process known as **eutrophication**).
- Lack of oxygen can hurt aquatic life, causing fish kills.
- Algal blooms also choke out rooted vegetation by blocking light penetration.
- The majority of algal blooms are the result of human interference, although algal blooms do occur naturally, their occurrence is insignificant in comparison to human produced algal blooms.
- Phosphorus in lakes can be stored in sediment and resuspended in water columns with spring and fall overturns.

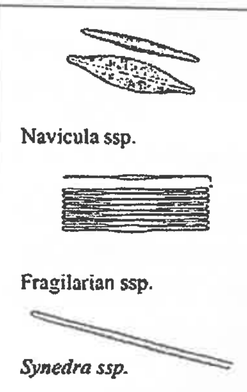


Fig. 2. Some freshwater algae that thrive on higher nutrient levels.

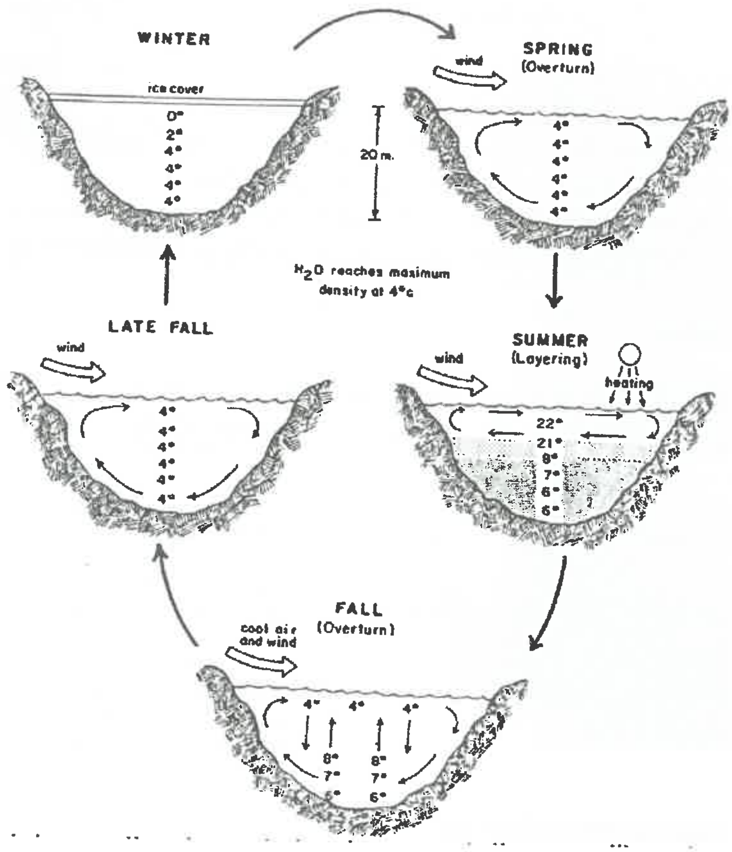


Illustration source: *Amos, 1969.* *Limnology: An Introduction to the Fresh Water Environment*

- Draining wetlands and clearing vegetation can liberate phosphorus that was trapped in soil and organic matter.

Water Quality:

- Even relatively small Phosphorus inputs, (<0.03mg/L), can stimulate excessive vegetative growth.
- The EPA states that the Phosphorus concentration in sewage waste should be less than 1 mg/L.

Links:

1. Phosphates~General overview on phosphates
   http://www.state.ky.us/nrepc/water/wcptp.htm
   http://www.water-research.net/phosphate.htm
2. PO_4~More background information
   http://www.epa.gov/volunteer/stream/vms56.html

TEMPERATURE FACT SHEET

Definition: A numerical measurement in degrees Celsius (°C) or Fahrenheit (°F) of heat.

$$°C = \frac{(°F - 32.0)}{1.80}$$

$$°F = (°C \times 1.80) + 32.0$$

Background:

- Many of the physical, chemical, and biological characteristics of a waterway are directly linked to the water temperature.
- The sun provides the energy needed to affect water temperatures, so shading influences temperature.

- The shallower the water, the quicker water temperature will change.
- Moving water (stream, rivers, especially riffles and rapids) is normally cooler than standing water, (ponds, lakes).
- Colder water holds more oxygen, hotter holds less.
- Higher temperatures increase aquatic organisms' metabolic rates… (increase oxygen need).
- Higher temperatures increase plant growth and decomposition rates.
- Different species have specific ideal temperature ranges.

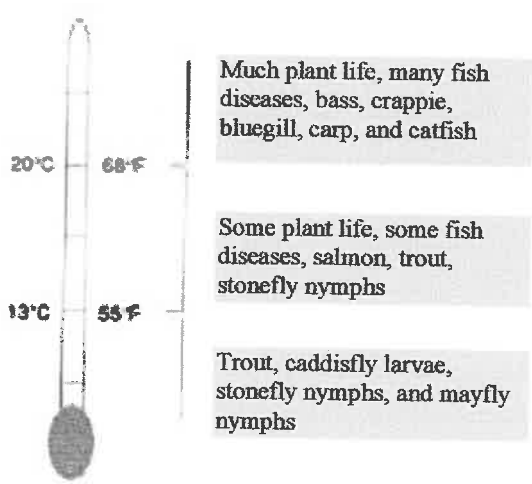


Fig. 1: The temperature tolerances of aquatic life.

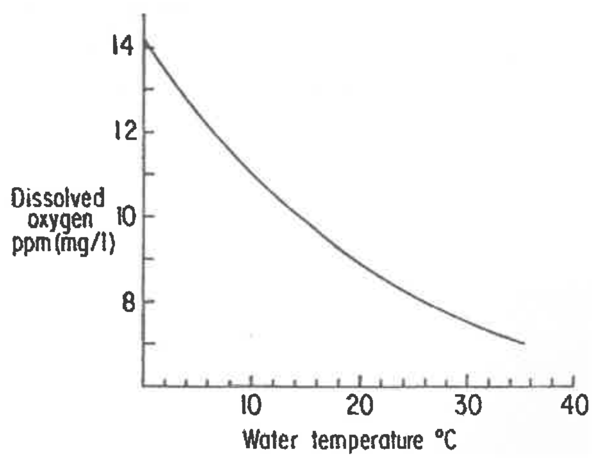


Fig. 2: Relationship between temperature and dissolved oxygen in pure water at sea level pressure.

Sources of figures 1 and 2: From or based upon Caduto, 1985. Pond and Brook: A Guide to Nature In Freshwater Environments.

Thermal Pollution

Definition: When relatively warmer or colder water enters a body of water, causing unnatural changes in the temperature of the body of water.

Why is this bad?
An aquatic organism's body temperature is directly linked to water temperature. Thus, the organism needs time to adjust to any change in water temperature. Sudden changes in water temperature (as in thermal pollution) places stresses on the organism too quickly to adjust to the water temperature, (Thermal change of $\geq 2°$ C per day is harmful). If thermal pollution is severe, then the entire aquatic ecosystem can be destroyed.

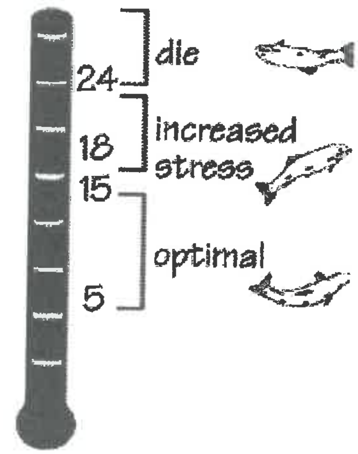


Fig. 3: The stress of increased temperature (°C) on trout and salmon Illustration Source: www.busboy.sped.akons.edu/nkancm/stream/chemical/tempby.shtml

Origins of Thermal Pollution:
- Industries & power plants--- warm discharge water used to cool hot machinery.
- Stormwater---running off of hot urban surfaces such as pavement.
- Cutting of trees along waterways that shade the water from the sun.
- Increased turbidity, (water cloudiness)... Cloudy water absorbs the sun's rays.

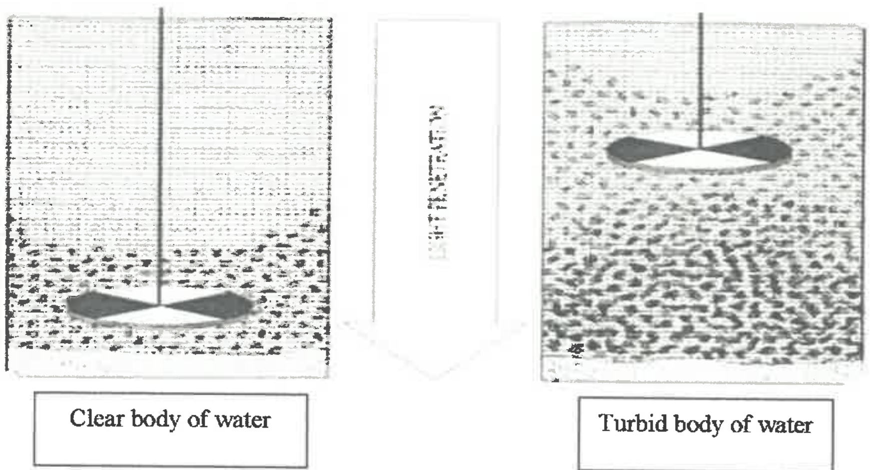
Links:
1. *Thermal Pollution*
http://www.rpi.edu/dept/chem-eng/Biotech-Environ/Environmental/THERMAL/ttel.html

2. *Temperature Change*
http://eesc.orst.edu/agcomwebfile/edmat/EC1489.pdf
http://www.epa.gov/volunteer/stream/vms53.html

3. *Temperature Effects on Fish*
http://web.ics.purdue.edu/~jordanb/fish_temperature.htm

TURBIDITY FACT SHEET

Definition: Cloudiness of the water, caused by suspended materials that can be seen and scatter the light, which passes through the water… (Turbid waters are those in which you can not see your feet in knee deep water).



Background:

Causes of Turbidity:
- Soil Erosion,
- Waste Discharge,
- Urban Runoff,
- Bottom feeders, such as carp, kick up sediment as they search for food on the bottom of the waterway,
- Algal growth.

Soil erosion and urban runoff in a suburb of Pittsburgh. Creek Connections photo.

Consequences of Turbidity:
- As turbidity increases, water loses its ability to support diverse aquatic organisms,
- It warms water by absorbing heat,
- It blocks photosynthesis,
- It irritates and clogs gills of fish,

- It irritates filter feeding insects and mussels,
- It smothers egg masses & nest sites,
- It carries nutrients and pesticides,
- It decreases visibility for predators and prey.

Water Quality:
- The EPA states that drinking water should not exceed 5 JTU for two consecutive days or have a monthly average of 1 JTU.
- Should not reduce photosynthetic activity any more than 10% of normal.

Links:

Turbidity~Additional background info on turbidity
http://www.epa.gov/volunteer/stream/vms55.html

http://waterontheweb.org/under/waterquality/turbidity.html

Evaluation of Water Quality in Ponds

Name________________________________PD_____

Use the provided macroinvertebrate cards to "survey" and evaluate each pond.

Pond A:

Column A - Tolerance	Column B – Number of Organisms	Column C – Total Tolerance

Pond B:

Column A - Tolerance	Column B – Number of Organisms	Column C – Total Tolerance

Multiply each number in column A with column B – Write that value in Column C. To calculate the overall water quality of the ponds sum Column C and divide that number by the sum of Column B.

Pond A Biotic Index:

Water Quality:

Pond B Biotic Index:

Water Quality:

Write a statement about the water quality and biodiversity of the two ponds.

Describe each water quality property and indicate the ranges found in a healthy body of water.

Turbidity – What is it? What are the normal values – include units.

Phosphorus– What is it? What are the normal values – include units.

Nitrates – What is it? What are the normal values – include units.

Dissolved Oxygen – What is it? What are the normal values – include units.

pH – What is it? What are the normal values – include units.

Temperature – What is it? What are the normal values – include units.

B	I	N	G	O
		Free Space		