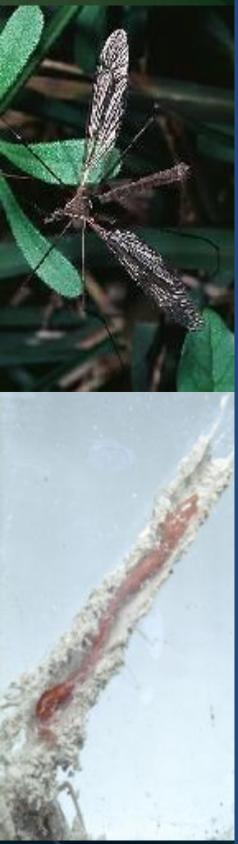




INTRODUCTION TO AQUATIC MACROINVERTEBRATES

John K. Jackson, Ph.D.
Stroud Water Research Center
jkjackson@stroudcenter.org


Questions I will address today:

1) Why do I study aquatic macroinvertebrates?

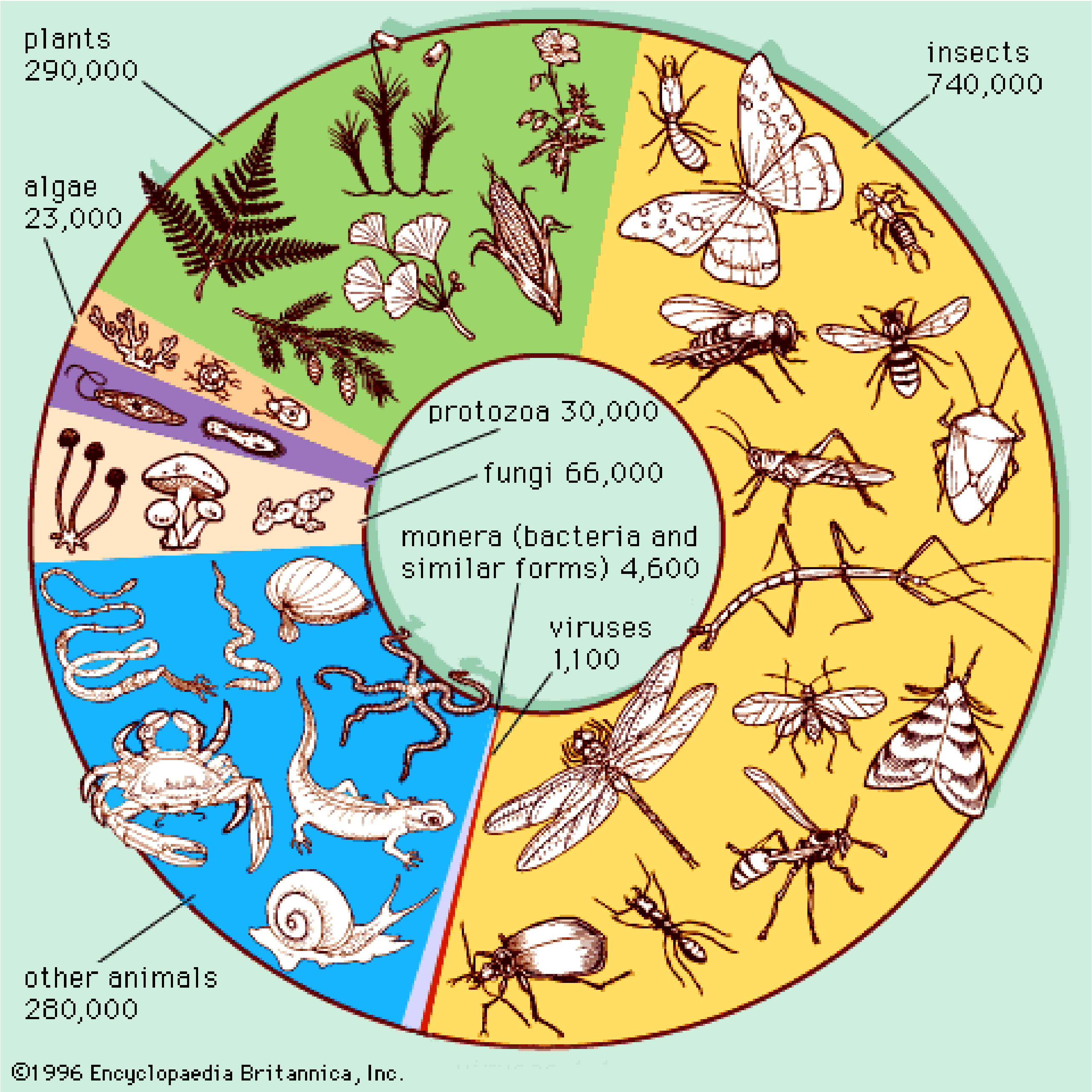
2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

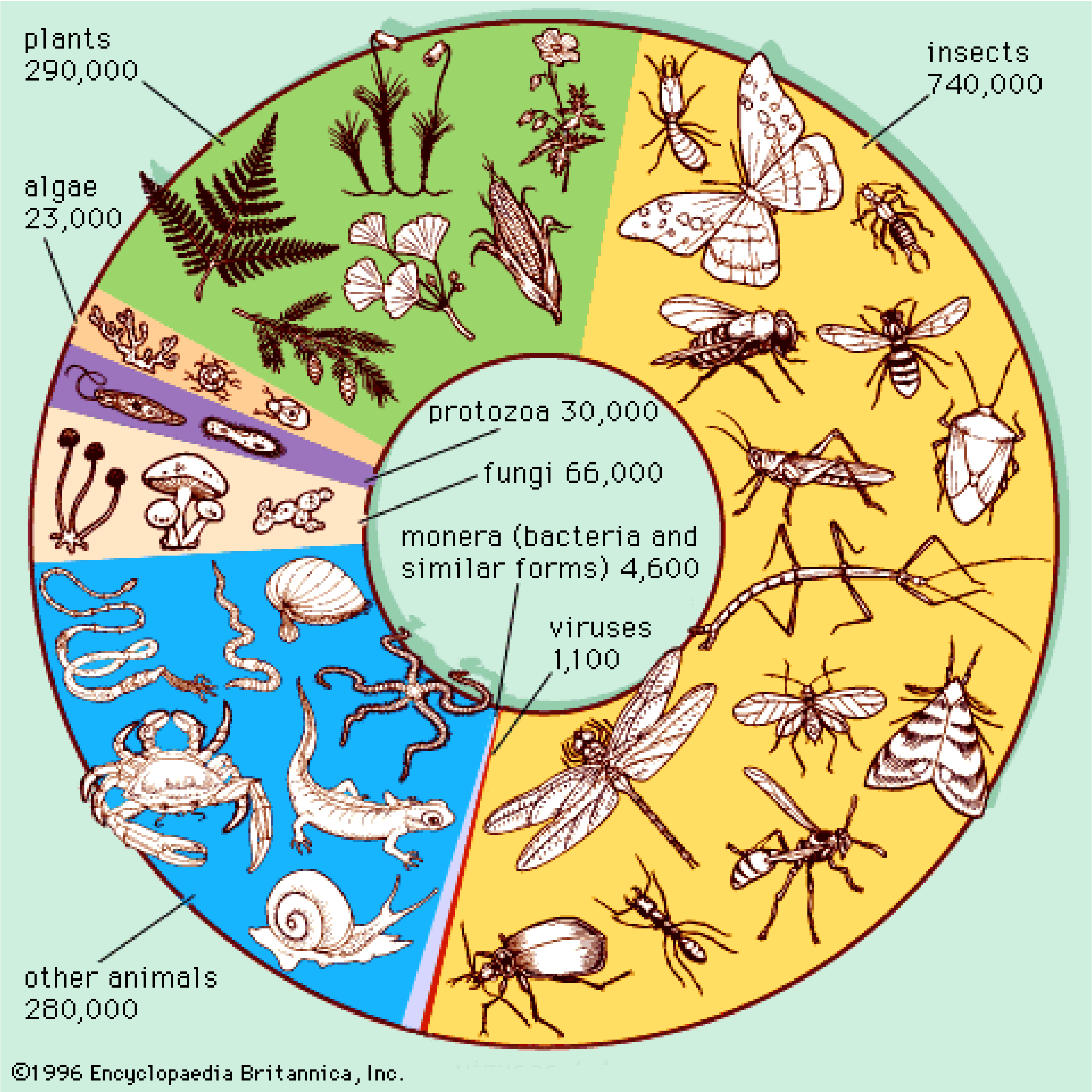
5) What determines species richness and diversity – aquatic or terrestrial?

STROUD WATER RESEARCH CENTER



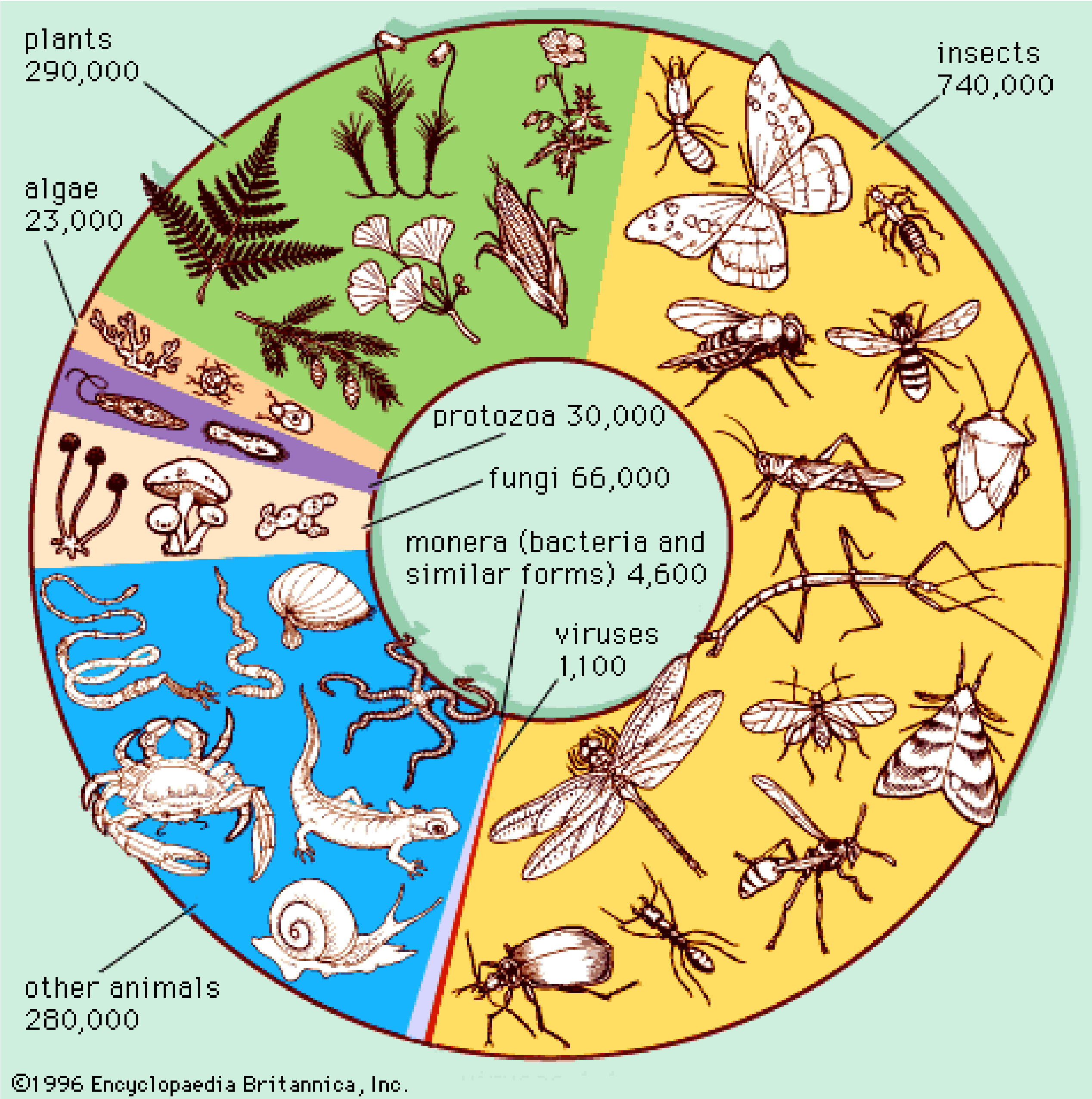
Invertebrate = an animal lacking a backbone.

STROUD
WATER RESEARCH CENTER



Invertebrate = an animal lacking a backbone.

Examples include an arthropod, mollusk, worm, etc.



Invertebrate = an animal lacking a backbone.

Examples include an arthropod, mollusk, worm, etc.

Represent 95% of animal species

STROUD™
WATER RESEARCH CENTER

Questions that I will address today:

1) Why do I study aquatic macroinvertebrates?

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

5) What determines species richness and diversity – aquatic or terrestrial?

STROUD WATER RESEARCH CENTER

Why do I study aquatic macroinvertebrates?

Big – Macro

Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant

STROUD WATER RESEARCH CENTER

Why do I study aquatic macroinvertebrates?

Big – Macro

Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant

STROUD™
WATER RESEARCH CENTER

What are Macroinvertebrates?

Macroinvertebrates

> 0.5 – 1mm, visible without magnification, no backbone

Crayfish, mussels, snails, worms, **insects**

http://www.nzfreshwater.org/pictures/macroinvertebrate_collage.jpg

What are Macroinvertebrates?

Benthic Macroinvertebrates

Insects….

Aquatic Macroinvertebrates

Primarily aquatic insects

Mayflies

Stoneflies

Caddisflies

STROUD WATER RESEARCH CENTER

Aquatic Macroinvertebrates

Also non-insects

Mussels

Crayfish

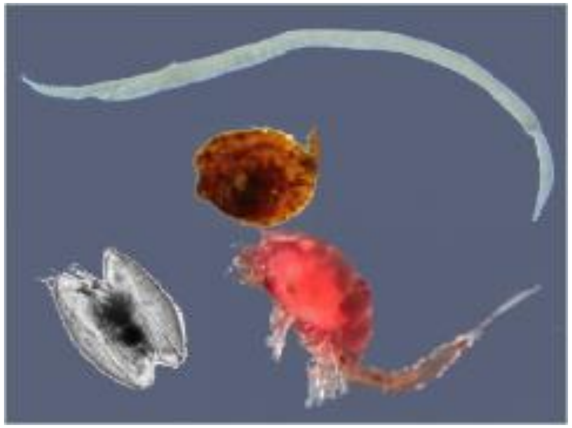
Snails

Stroud Water Research Center

What is Meiofauna?

Meiofauna

- < 0.5 mm (1 mm) – protozoans and metazoans (as small as 10 um)
  - Protozoans (unicelluar eukaryotes) – i.e., cilliates, flagellates, amoebiods, sporosoans
  - Metazoans (multicelluar eukaryotes, animals) – i.e., rotifers, tardigrads, sponges, nematods, crustaceans…**and small insects**



http://www.hydrothermalvent.com/php/images/stories/research/meiosucc/meiofauna_skal.jpg

STROUD WATER RESEARCH CENTER

Why do I study aquatic macroinvertebrates?

Big – Macro

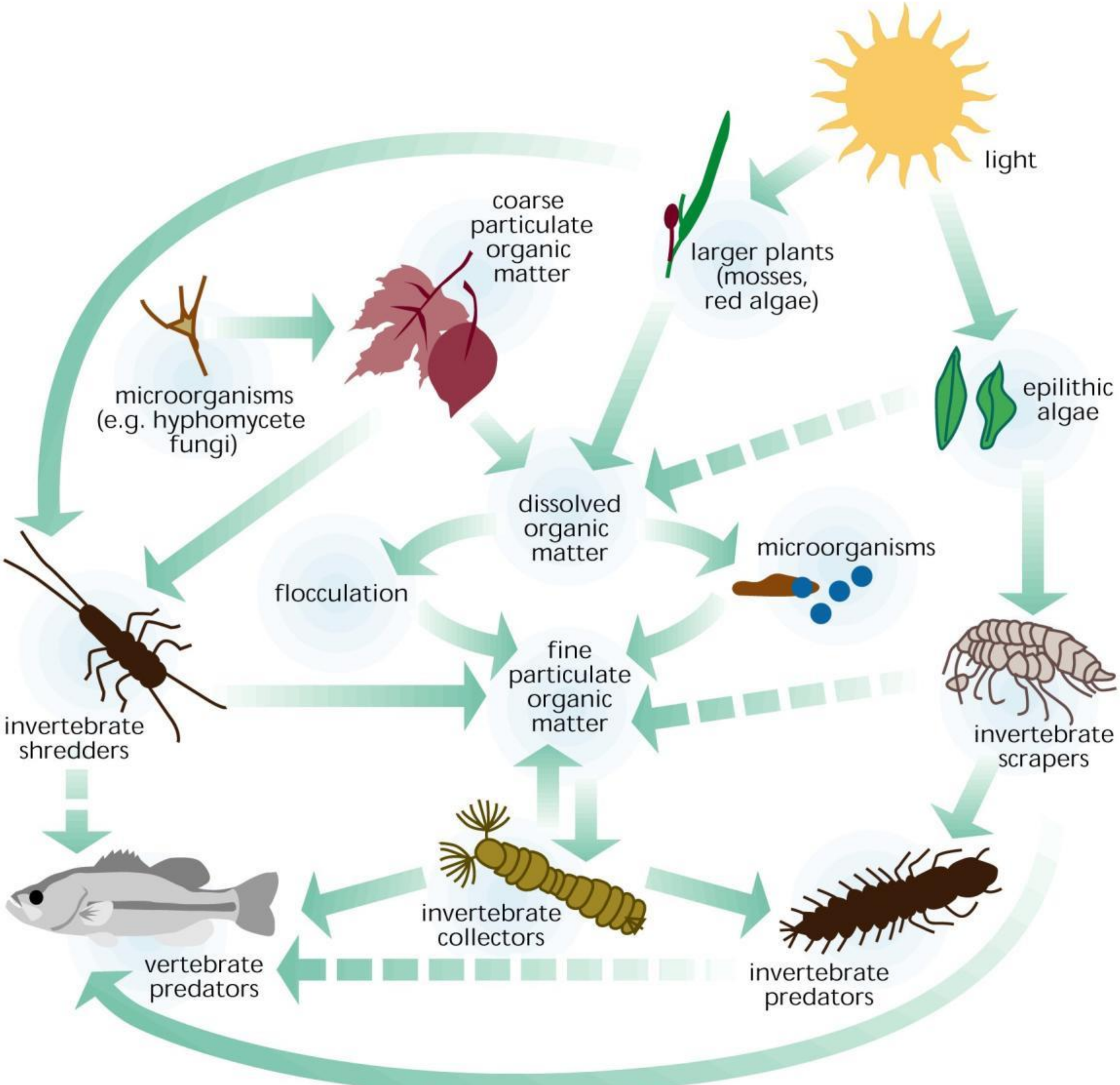
Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant

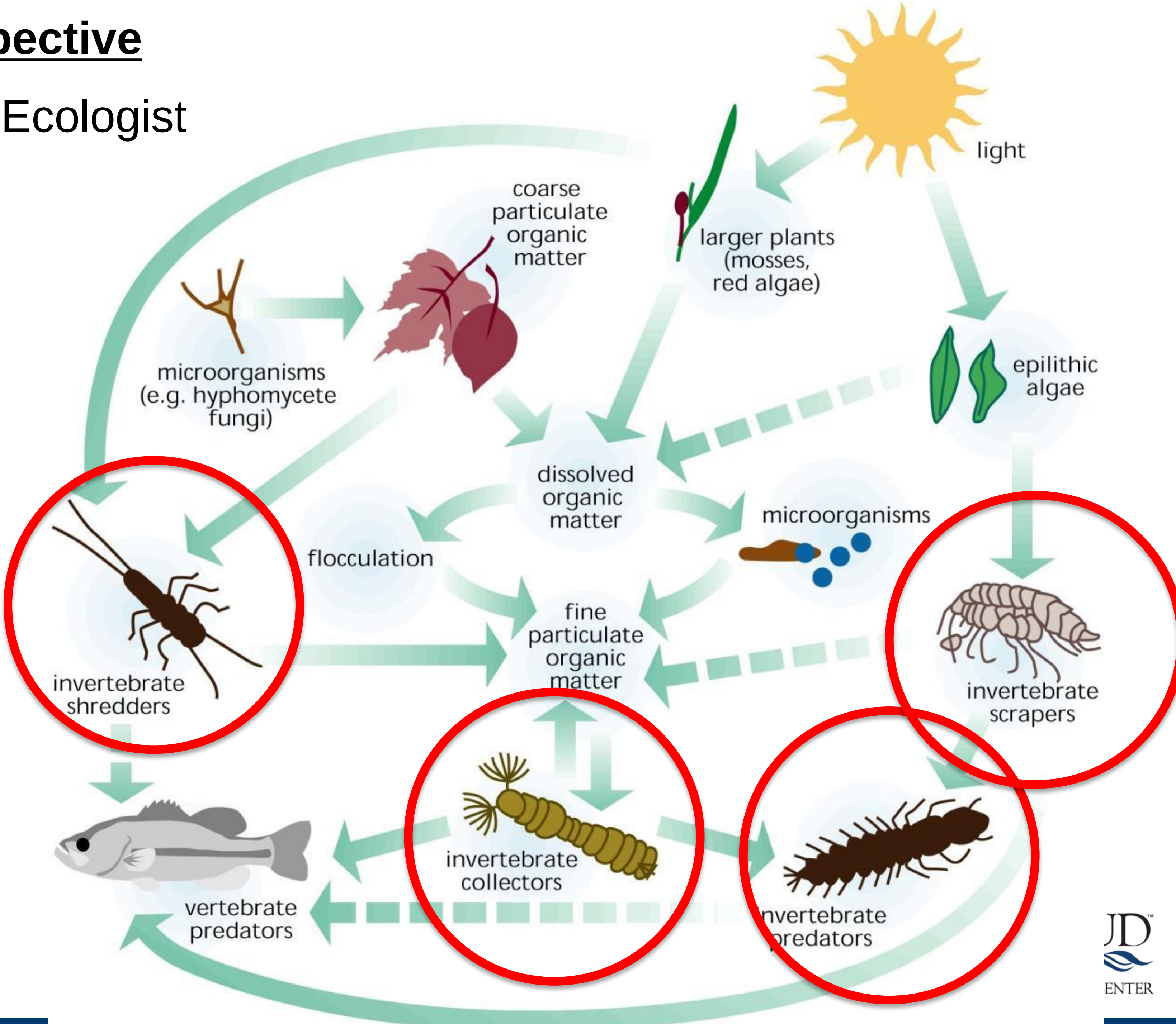
Stroud Water Research Center

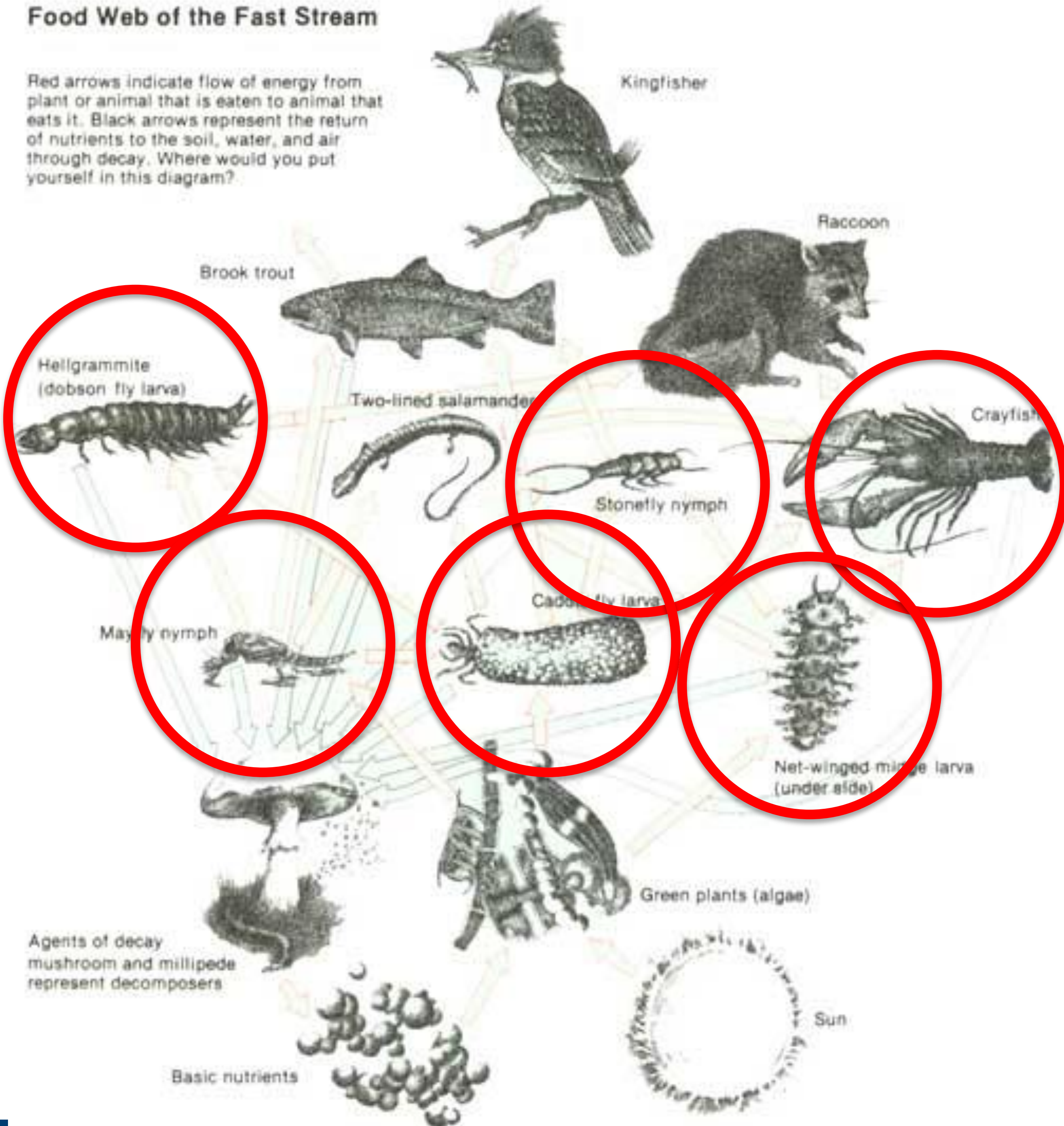


STROUD™
WATER RESEARCH CENTER

Perspective

Stream Ecologist





Perspective

Audubon
USFW
Trout Unlimited
Ducks Unlimited

STROUD Water Research Center

Why do I study aquatic macroinvertebrates?

Big – Macro

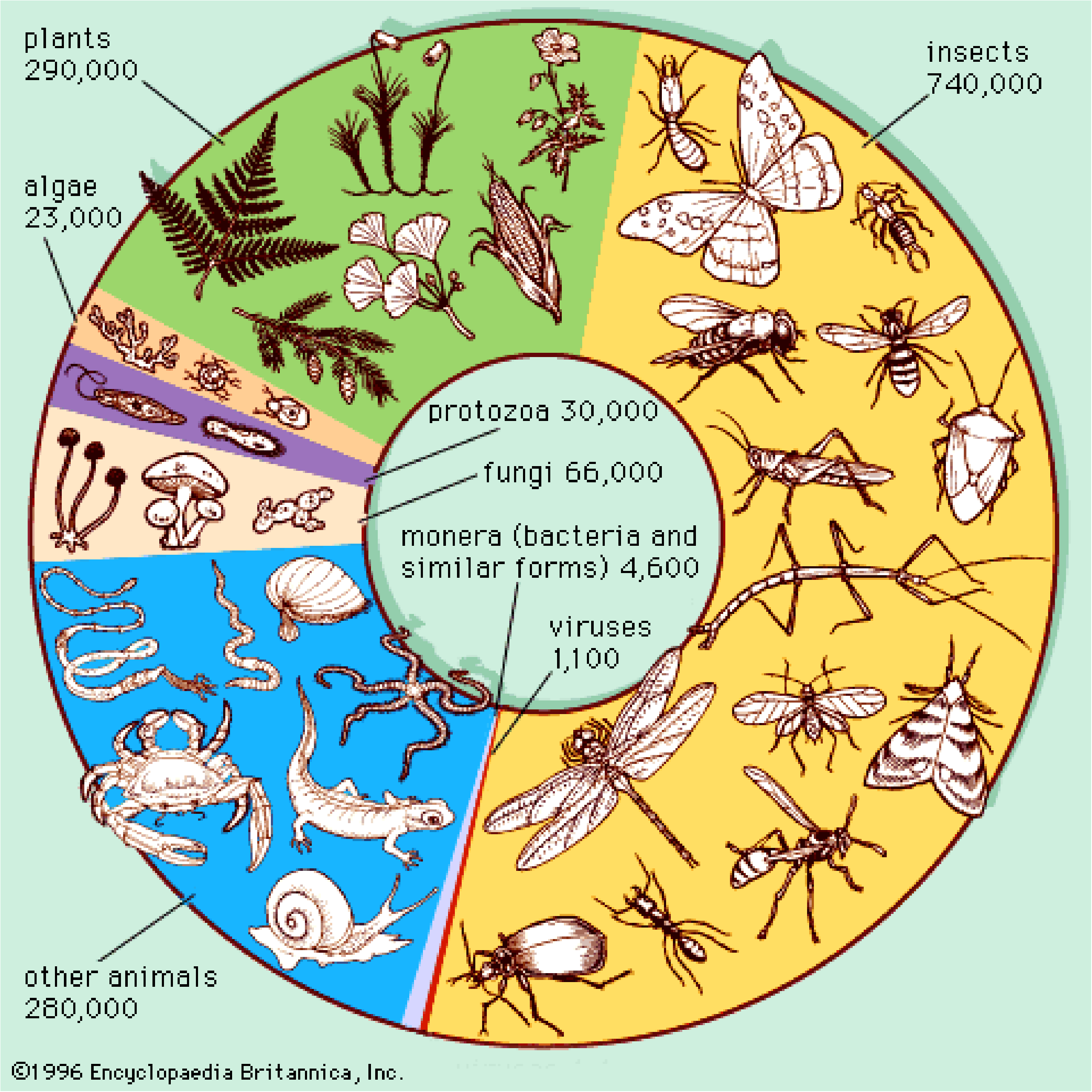
Ecologically Important

Numerous Species

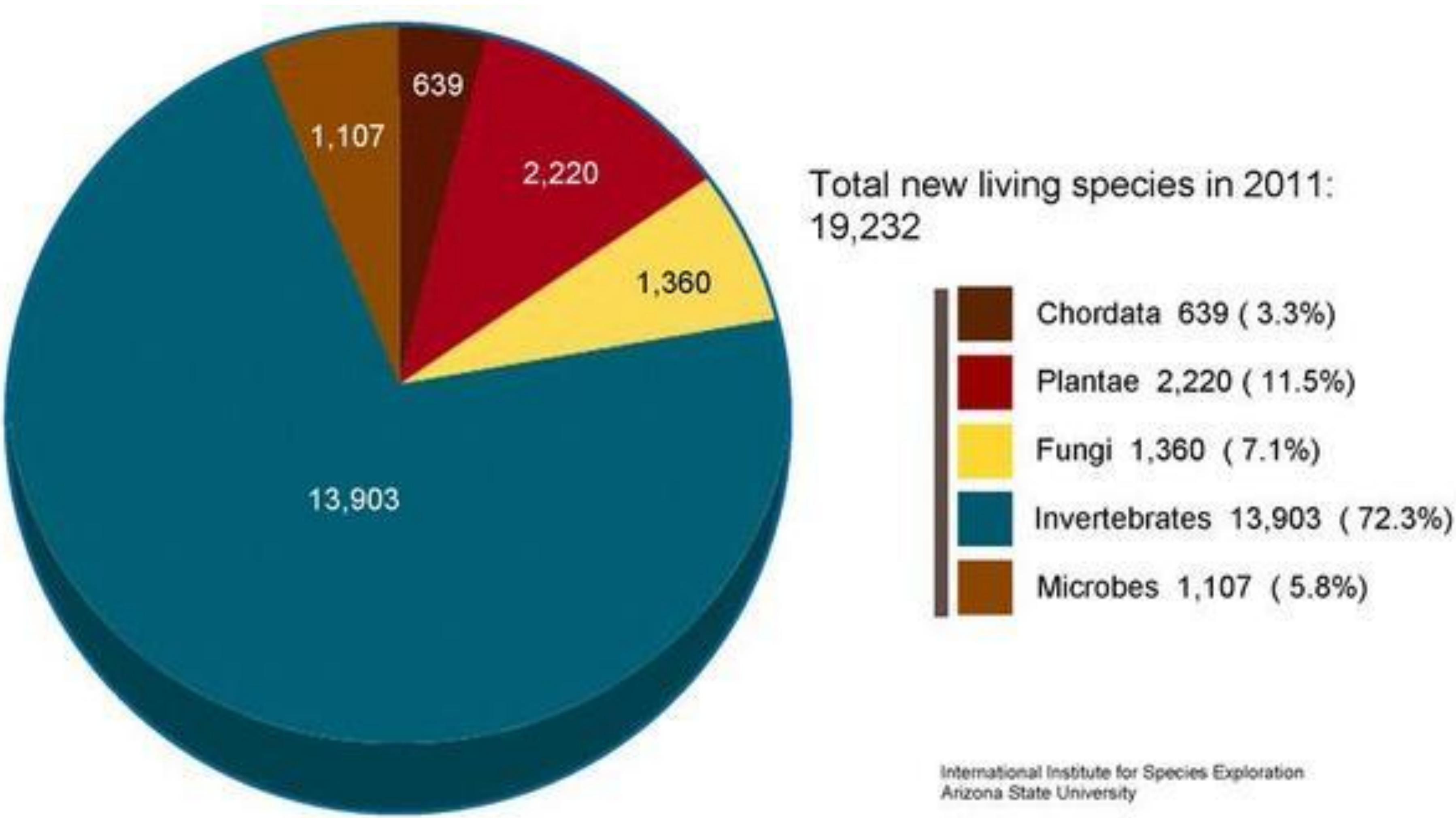
Different Pollution Tolerances

Abundant

STROUD
WATER RESEARCH CENTER



STROUD
WATER RESEARCH CENTER



STROUD WATER RESEARCH CENTER

White Clay Creek at Stroud Center

Over 50 years

Insect Order	Species
Ephemeroptera	52
Odonata	14
Plecoptera	19
Hemiptera	9
Trichoptera	55
Megaloptera	5
Lepidoptera	1
Diptera	118
Total	298

Genus/Species

White Clay Creek, Chester Co, PA

2 nearby sites, 1 collection date

Amateurs	26
Expert – genus	67
Expert – species	88
Genetics	150

STROUD WATER RESEARCH CENTER

Why do I study aquatic macroinvertebrates?

Big – Macro

Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant

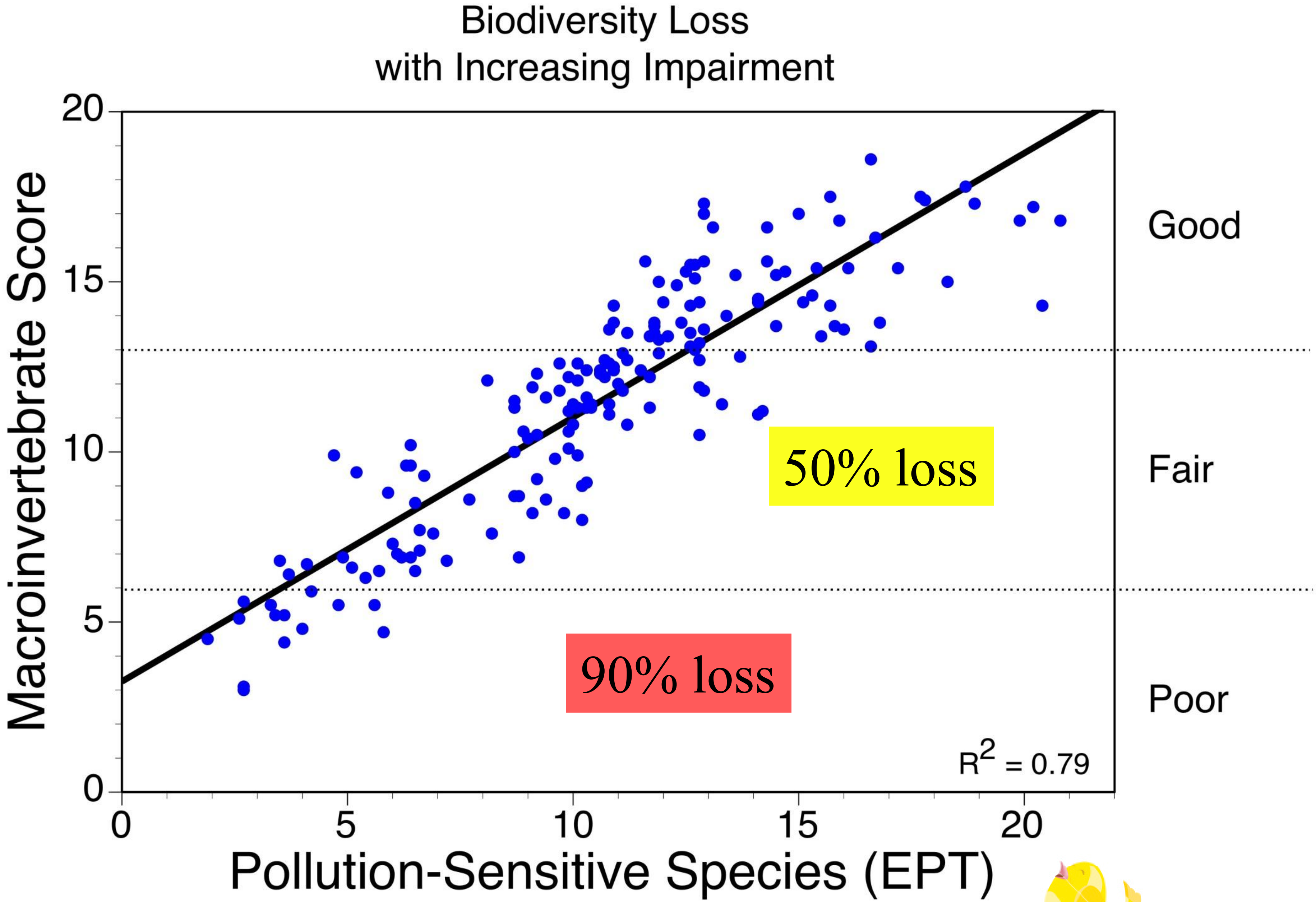
Ephemeroptera
Plecoptera
Trichoptera

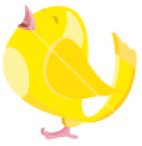
Pollution-sensitive

STROUD WATER RESEARCH CENTER

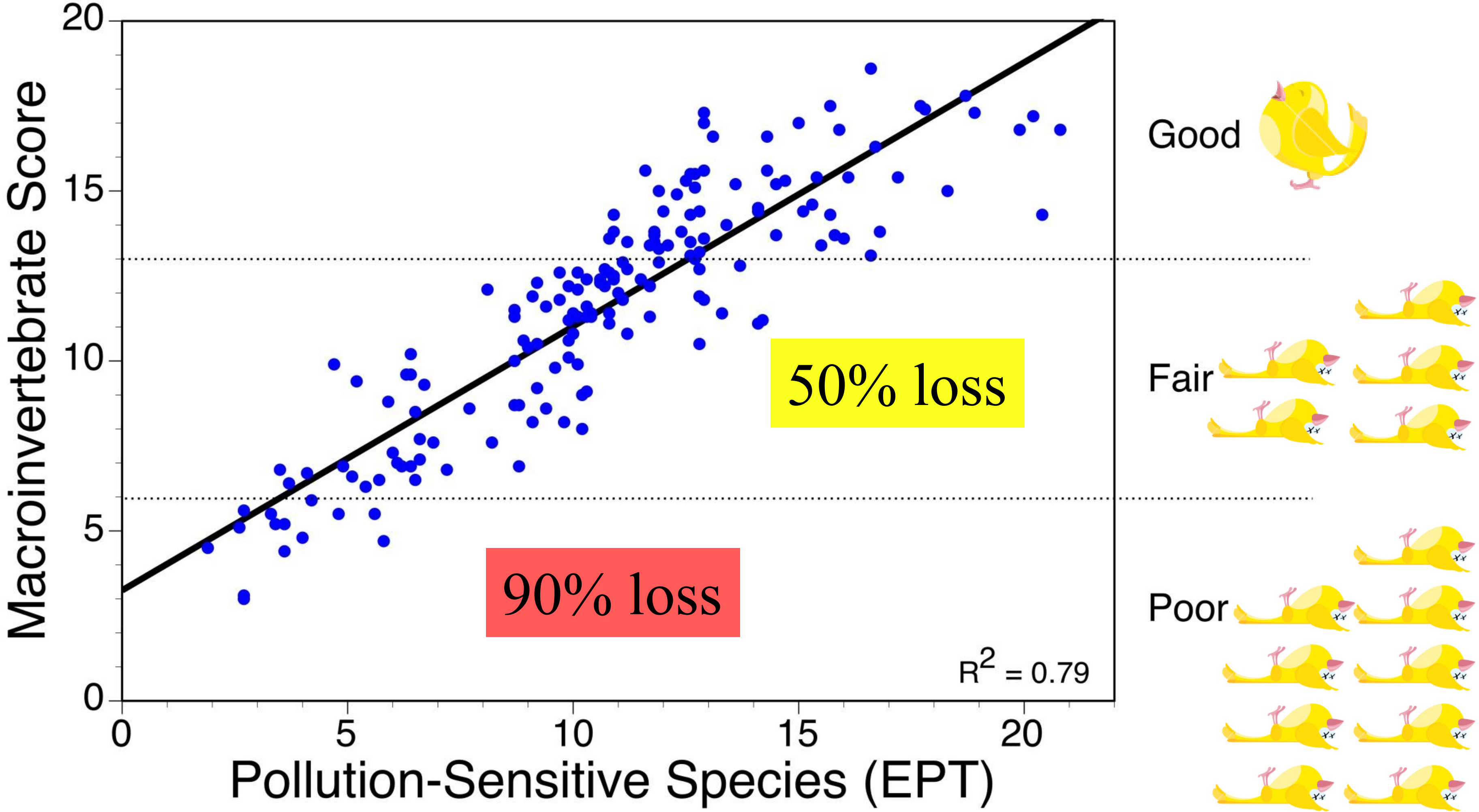
Pollution-sensitive species are our canaries in the coal mine

STROUD WATER RESEARCH CENTER


Biodiversity Loss
with Increasing Impairment
Macroinvertebrate Score
20
15
10
5
0
0
5
10
15
20
Pollution-Sensitive Species (EPT)
Good
Fair
Poor
50% loss
90% loss
$R^2 = 0.79$



Biodiversity Loss with Increasing Impairment



STROUD
WATER RESEARCH CENTER

Pollution-tolerant

STROUD WATER RESEARCH CENTER

Why do I study aquatic macroinvertebrates?

Big – Macro

Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant

What do I mean by abundant?

10,000 – 100,000 individuals/m^2

or

1,000 – 10,000 individuals/ft^2

1 floor tile = 1 ft^2

Average macroinvertebrate densities (individuals/m^2) among 10 spring seeps, two 2nd-order stream sites, and four 3rd-order stream sites in White Clay Creek near Stroud Center.

Site	Insect	Non-Insect	Total	% Insect
Spring Seep	10,601	5,083	16,707	68%
2nd order stream	13,836	3,237	17,073	81%
3rd order stream	14,153	1,987	16,140	88%

STROUD
WATER RESEARCH CENTER

Average macroinvertebrate densities (individuals/m^2) among 10 spring seeps, two 2nd-order stream sites, and four 3rd-order stream sites in White Clay Creek near Stroud Center.

Site	Insect	Non-Insect	Total	% Insect
Spring Seep	10,601	5,083	16,707	68%
2nd order stream	13,836	3,237	17,073	81%
3rd order stream	14,153	1,987	16,140	88%

STROUD WATER RESEARCH CENTER

Average macroinvertebrate densities (individuals/m^2) among 10 spring seeps, two 2nd-order stream sites, and four 3rd-order stream sites in White Clay Creek near Stroud Center.

Site	Insect	Non-Insect	Total	% Insect
Spring Seep	10,601	5,083	16,707	68%
2nd order stream	13,836	3,237	17,073	81%
3rd order stream	14,153	1,987	16,140	88%

STROUD
WATER RESEARCH CENTER

What do we know about aquatic macroinvertebrates?

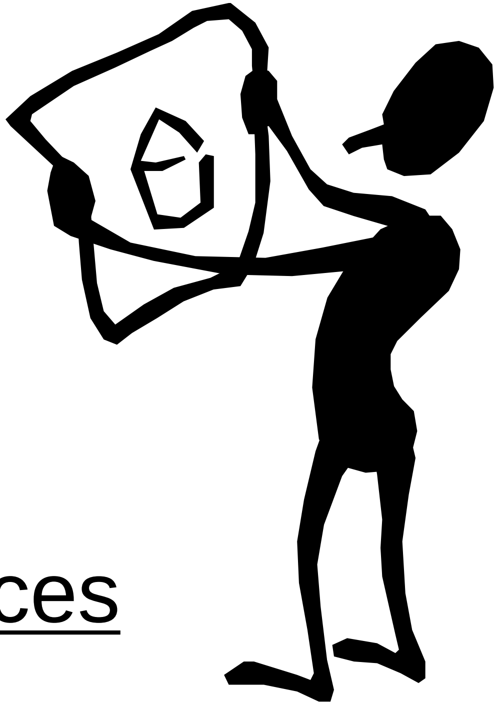
Big – Macro

Ecologically Important

Numerous Species

Different Pollution Tolerances

Abundant



STROUD WATER RESEARCH CENTER

Questions that I will address today:

1) Why do I study aquatic macroinvertebrates?

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

5) What determines species richness and diversity – aquatic or terrestrial?

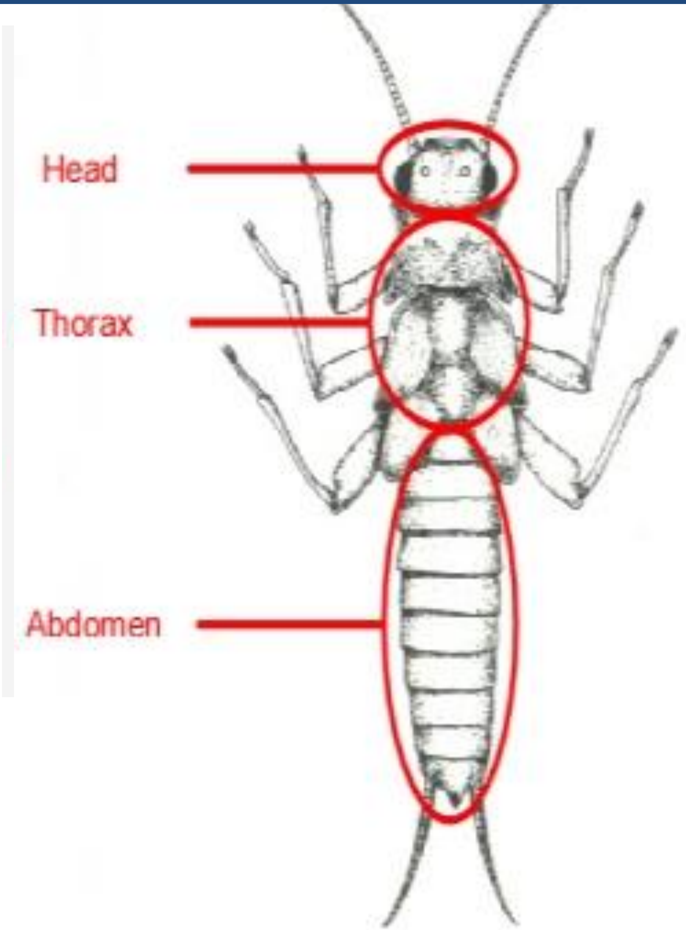
STROUD™ WATER RESEARCH CENTER

Arthropods

Invertebrate animals having an exoskeleton (external skeleton), a segmented body, and jointed appendages

Biological definition of an insect:

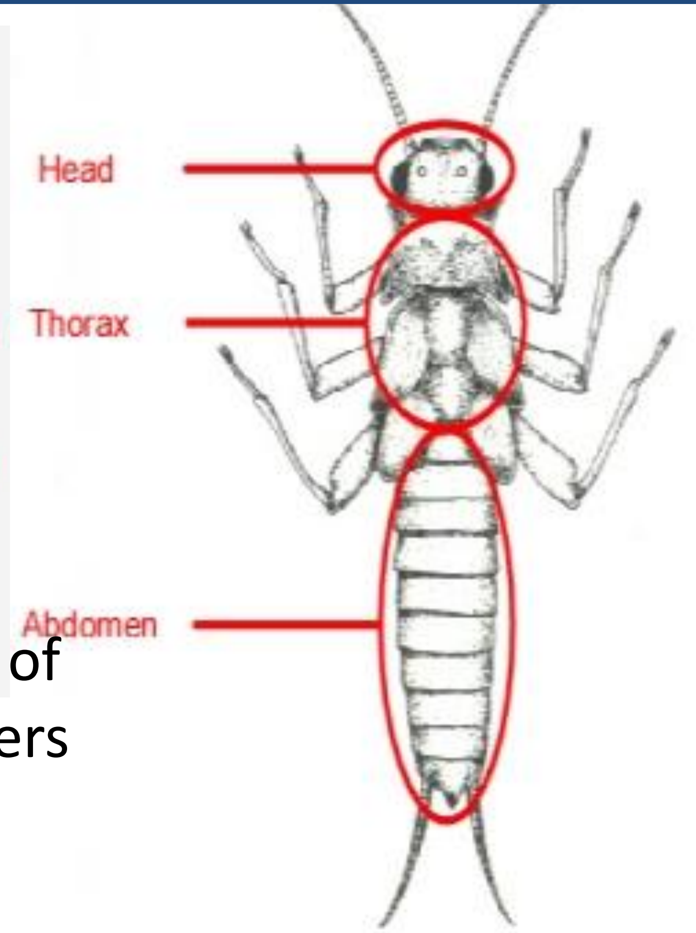
- arthropod (jointed exoskeleton),
- three body regions
  - head (6 segments)
  - thorax (3 segments)
  - abdomen (10-11 segments)
- 3 pairs of legs on the thorax



http://www.flyfishingentomology.com/index.html

Biological definition of an insect:

- arthropod (jointed exoskeleton),
- three body regions
  - head (6 segments)
  - thorax (3 segments)
  - abdomen (10-11 segments)
- 3 pairs of legs on the thorax



- one of the most successful groups of organisms, both in terms of numbers and breadth of distribution

- in almost any habitat in the world
  - hot springs to alpine ridges
  - tropical forests to driest deserts

http://www.flyfishingentomology.com/index.html

STROUD WATER RESEARCH CENTER

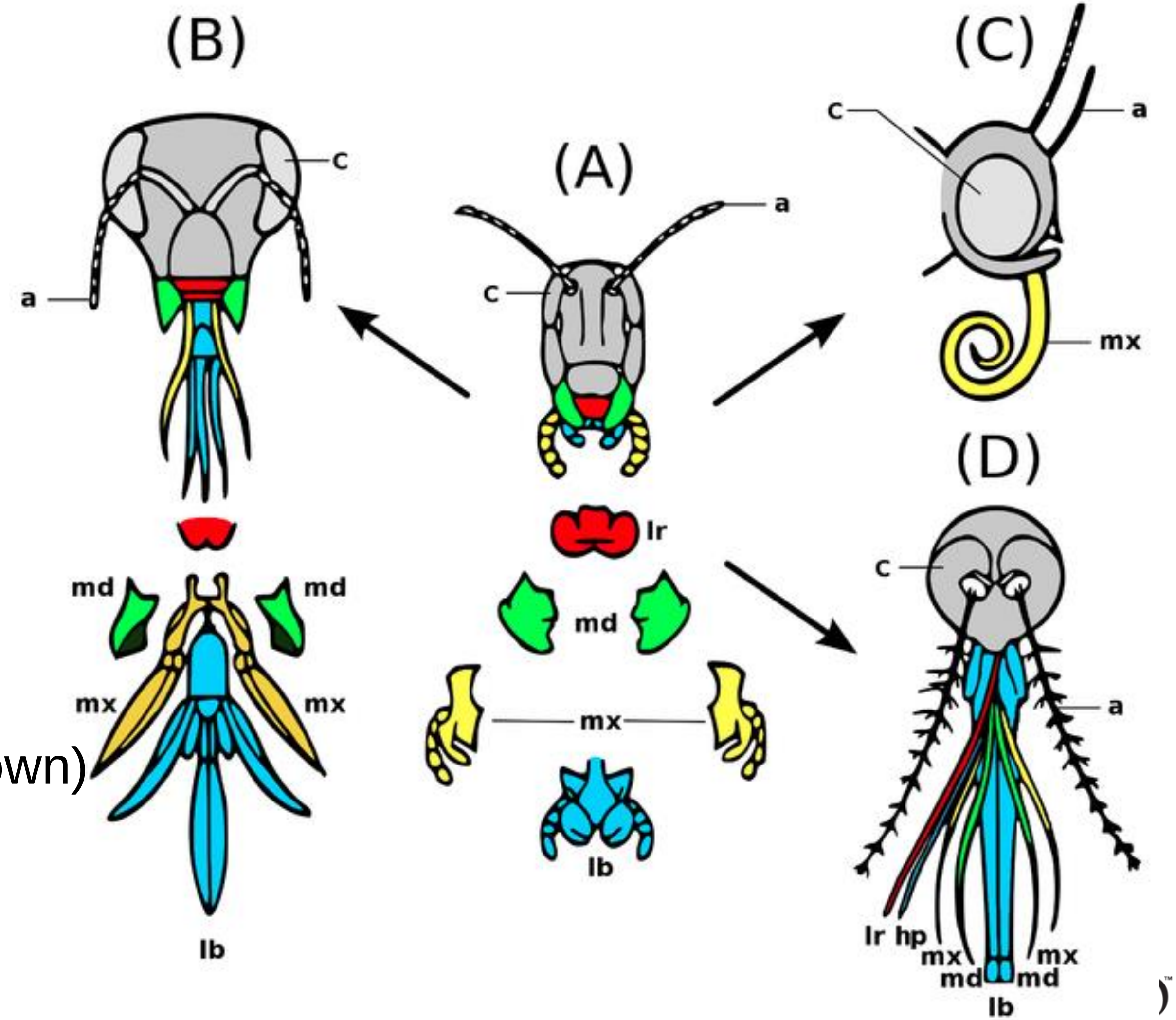
The biological success of the insects is due to six factors:

1) highly adaptable exoskeleton - locomotion, flight, water loss

Mouthparts

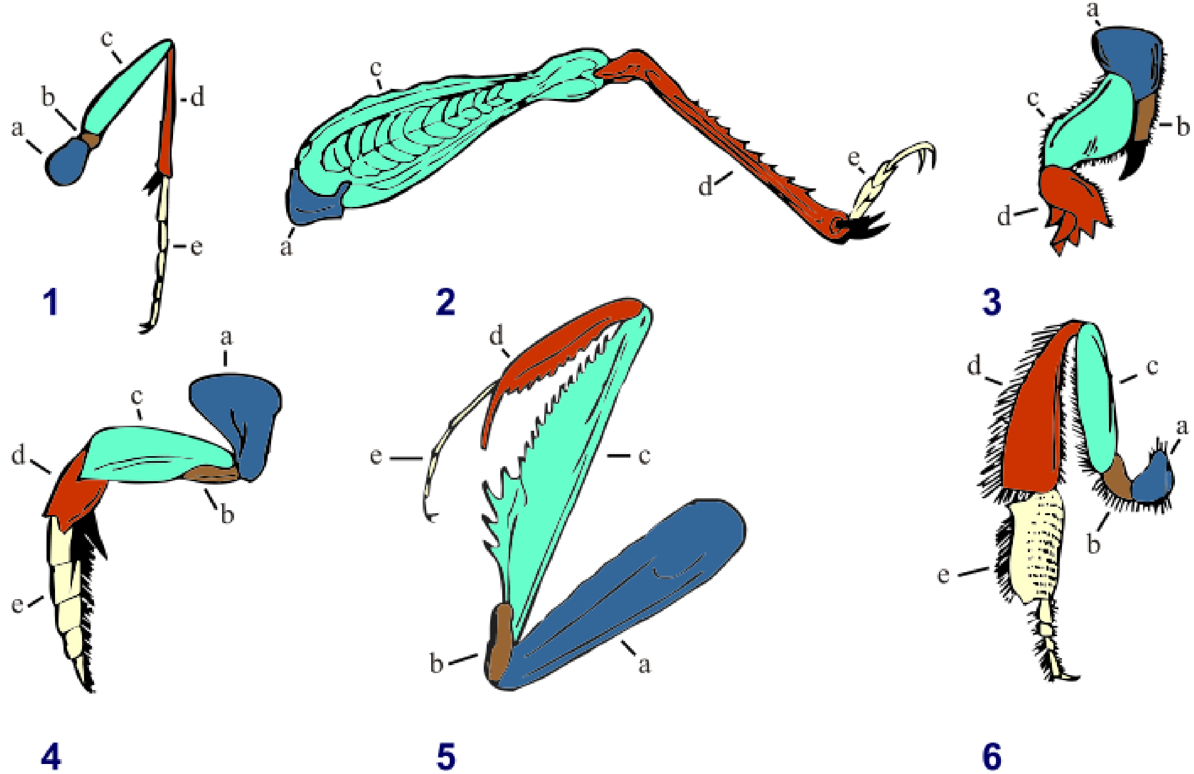
A – Chewing
B – Piercing
C – Siphoning
D – Lapping

(Not Shown)



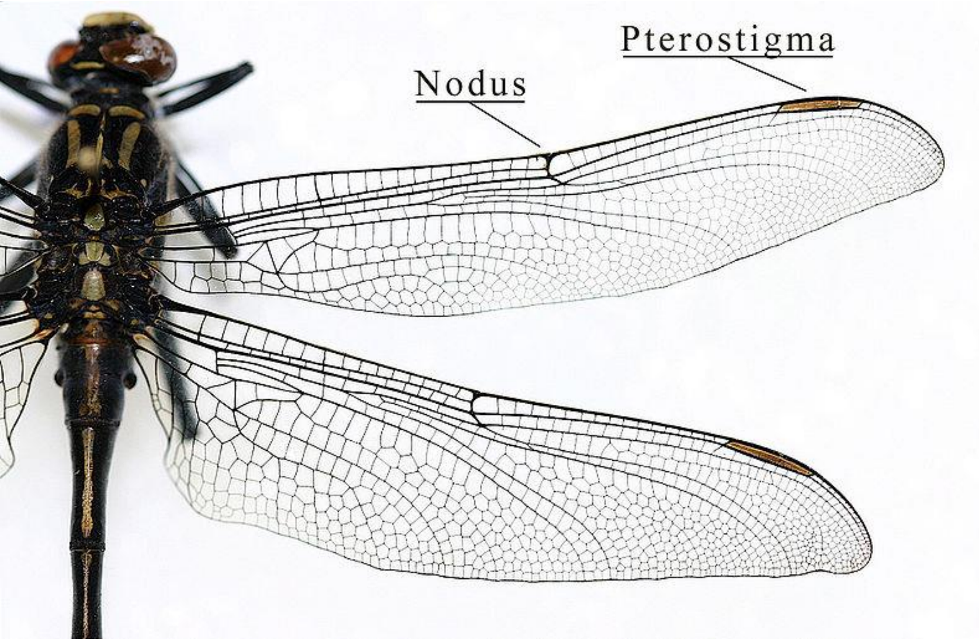
Legs

1 – Running
2 – Jumping
3 – Burrowing
4 – Swimming
5 – Grabbing
6 - Collecting

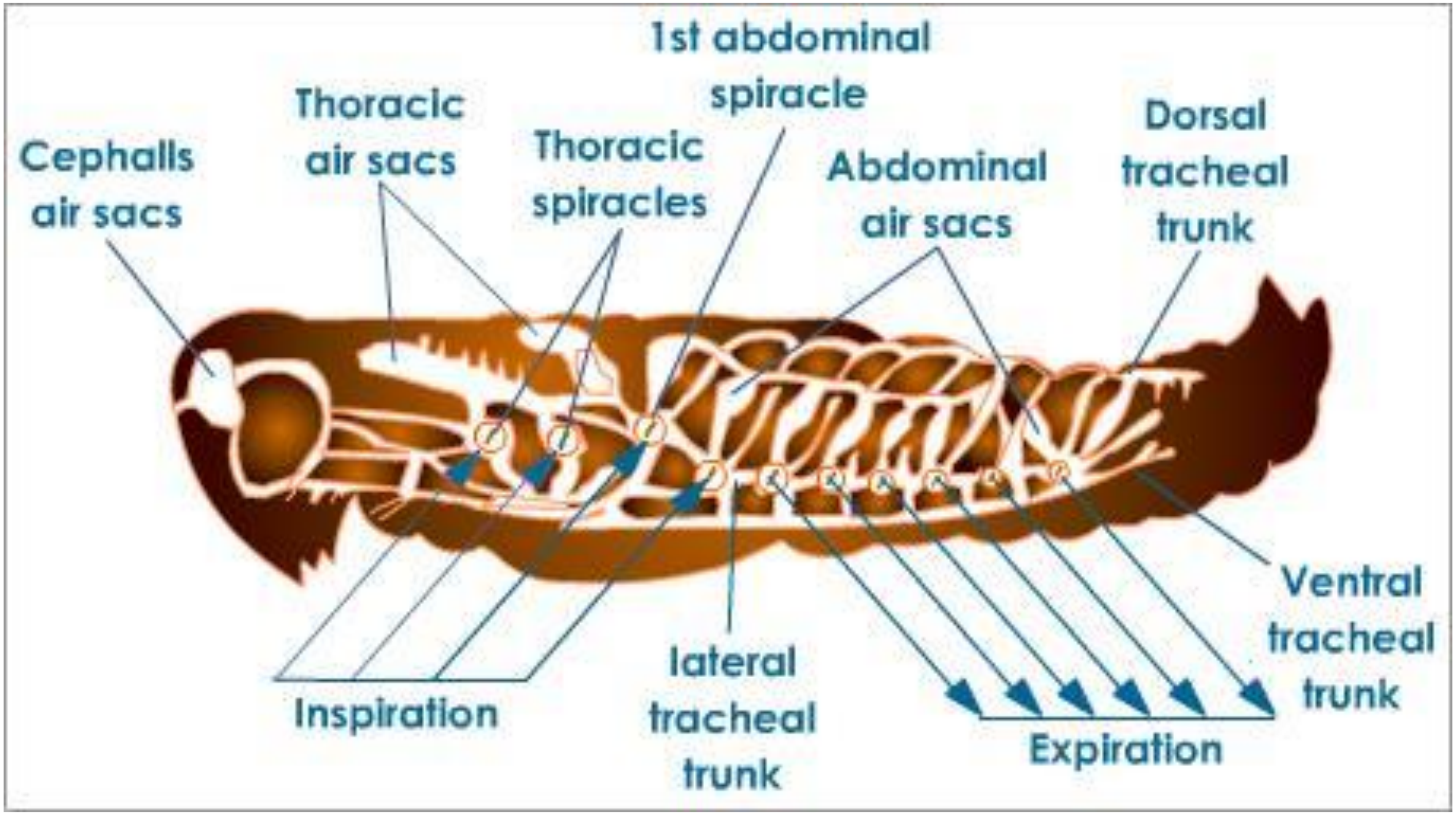


Stroud Water Research Center

Wings



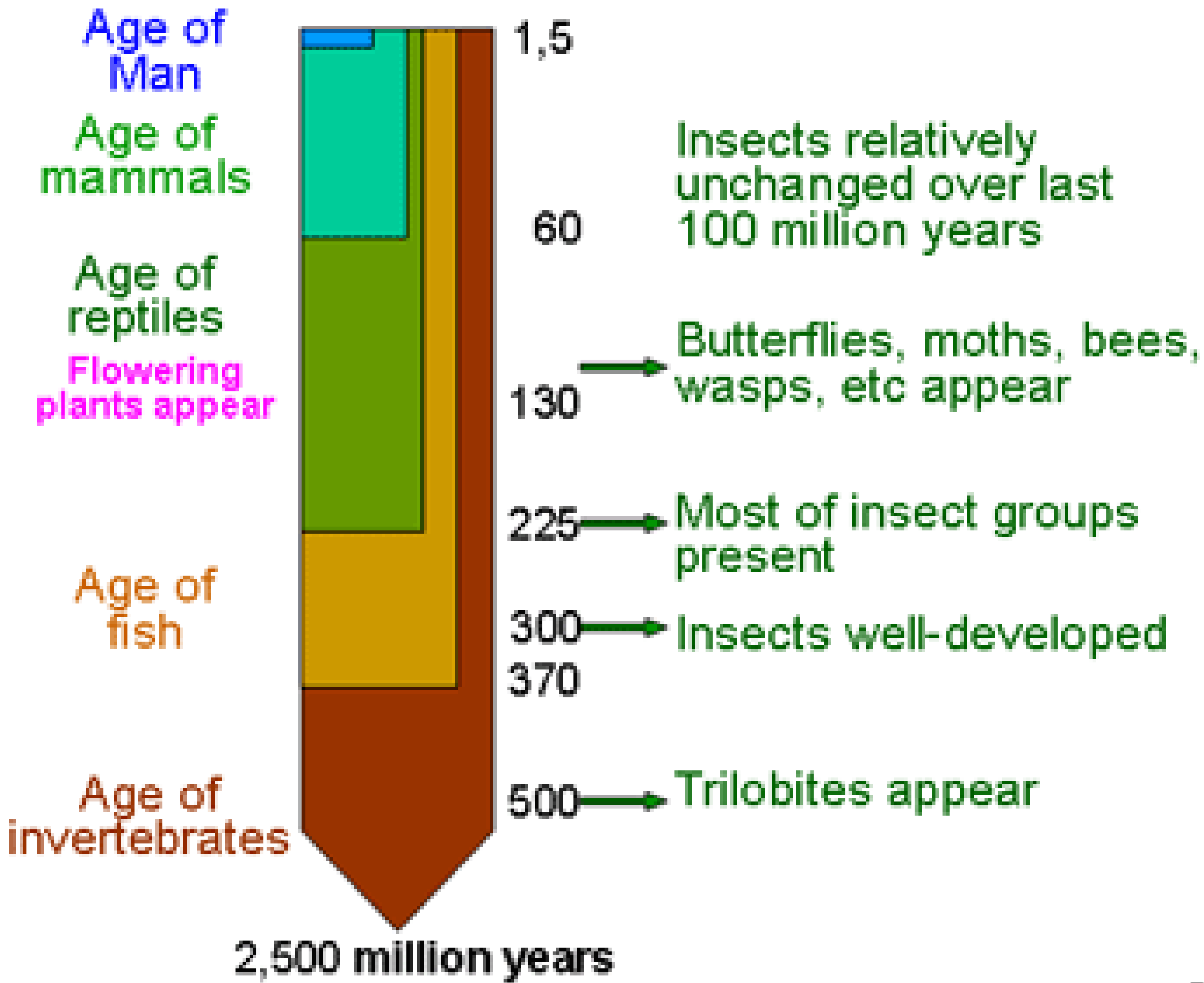
Tracheal System



The biological success of the insects is due to six factors:

1) highly adaptable exoskeleton - locomotion, flight, water loss
2) colonized terrestrial environment before chordates-competition

The history



Stroud Water Research Center





Zentimeter 1 2 3 4

The biological success of the insects is due to six factors:

1) highly adaptable exoskeleton - locomotion, flight, water loss
2) colonized terrestrial environment before chordates-competition
3) small body size
   - Water loss a disadvantage, large surface area to body volume
   - Exploit small niches
   - More abundant
     - less food to maturity
     - greater genetic diversity and cross breeding

STROUD™
WATER RESEARCH CENTER

What do I mean by abundant?

10,000 – 100,000 individuals/m^2

or

1,000 – 10,000 individuals/ft^2

1 floor tile = 1 ft^2

The biological success of the insects is due to six factors

4) short generation time and high birth rate

start with 2 individuals, 1 male, 1 female;

- reproduce at rate of 4, 100, 1000, with adult death
  - 1st 4 100 1000
  - 2nd 8 5000500,000
  - 3rd 16 250,000 250,000,000

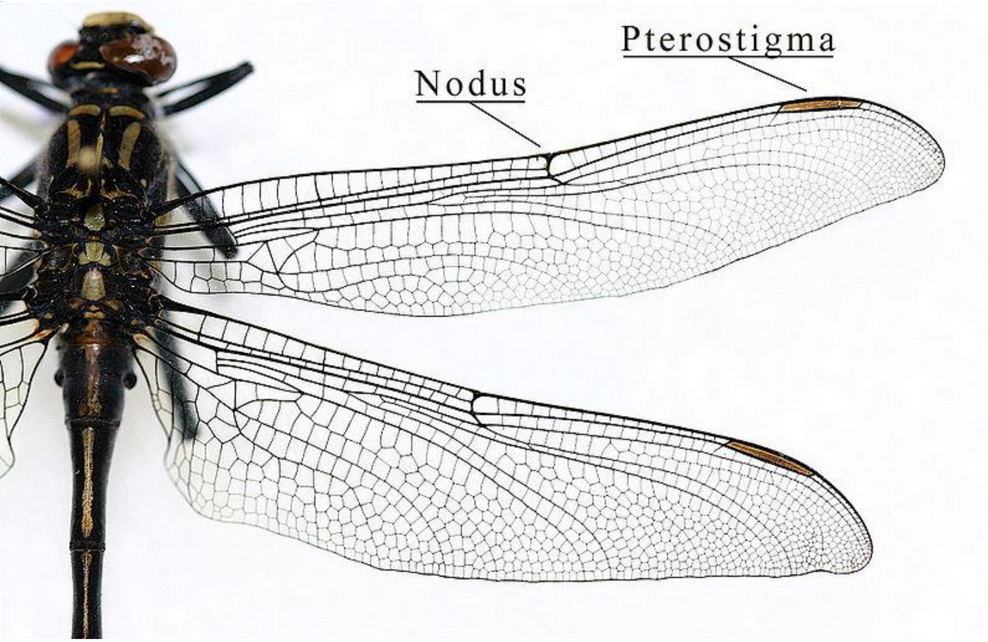
- Fortunately, mortality throughout the life cycle prevents us from seeing these kinds of numbers

5) highly efficient power of flight

escape enemies, find mates, food, places to lay eggs.

STROUD™ WATER RESEARCH CENTER

Wings



The biological success of the insects is due to six factors

4) short generation time and high birth rate

start with 2 individuals, 1 male, 1 female;

– reproduce at rate of 4, 100, 1000, with adult death

- 1st 4 100 1000
- 2nd 8 5000500,000
- 3rd 16 250,000 250,000,000

- Fortunately, mortality throughout the life cycle prevents us from seeing these kinds of numbers

5) highly efficient power of flight

escape enemies, find mates, food, places to lay eggs.

6) life history includes complete metamorphosis

adults are different than immatures

- serve different roles, exploit different habitats

STROUD™ WATER RESEARCH CENTER

Metamorphosis

- Metamorphosis important evolutionary development:

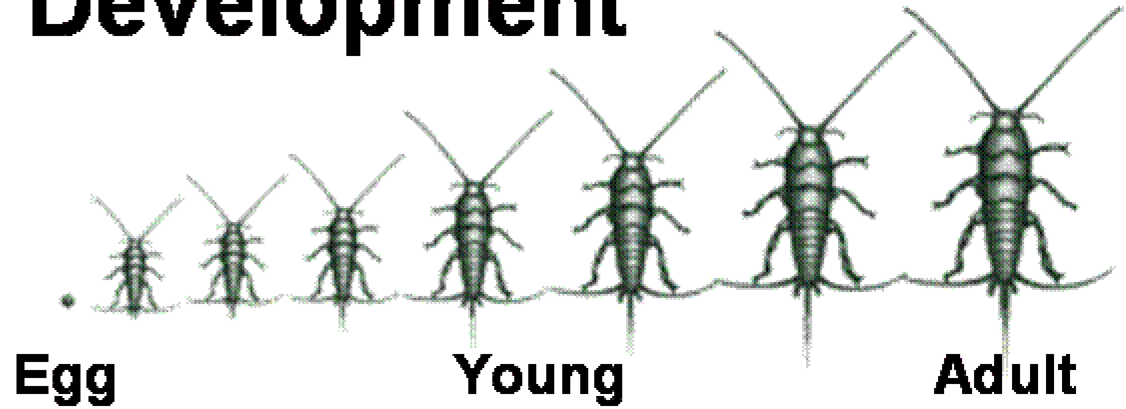
- Allows drastically different larval and adult anatomy
  - Larva & adult often specialize in different niches, fill different role in life cycle
  - Larvae specialize to feed and grow – caterpillar
  - Adults specialize to disperse and mate, and sometimes feed and grow – butterfly

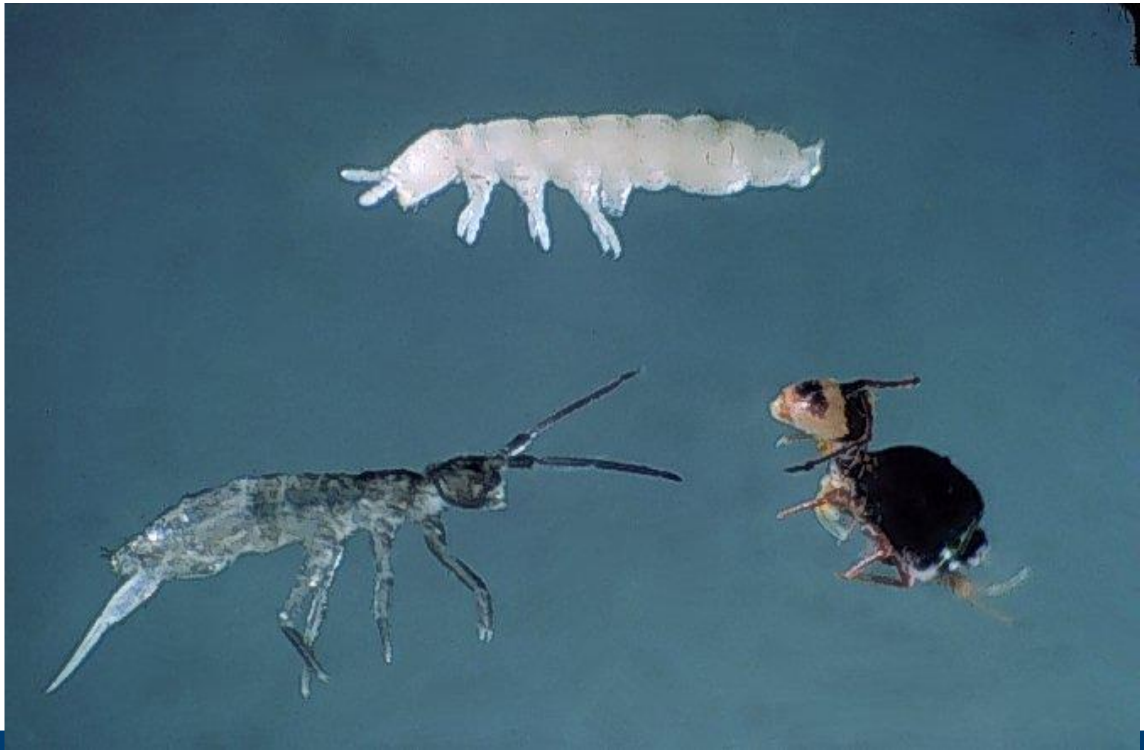
Metamorphosis

- Ametabolous – no metamorphosis
- Paurometabolous – little metamorphosis
- Hemimetabolous – half/simple/incomplete
- Holometabolous – complete metamorphosis
    - Ca. 88% of insects are holometabolous

STROUD™ WATER RESEARCH CENTER

Ametabolous Development



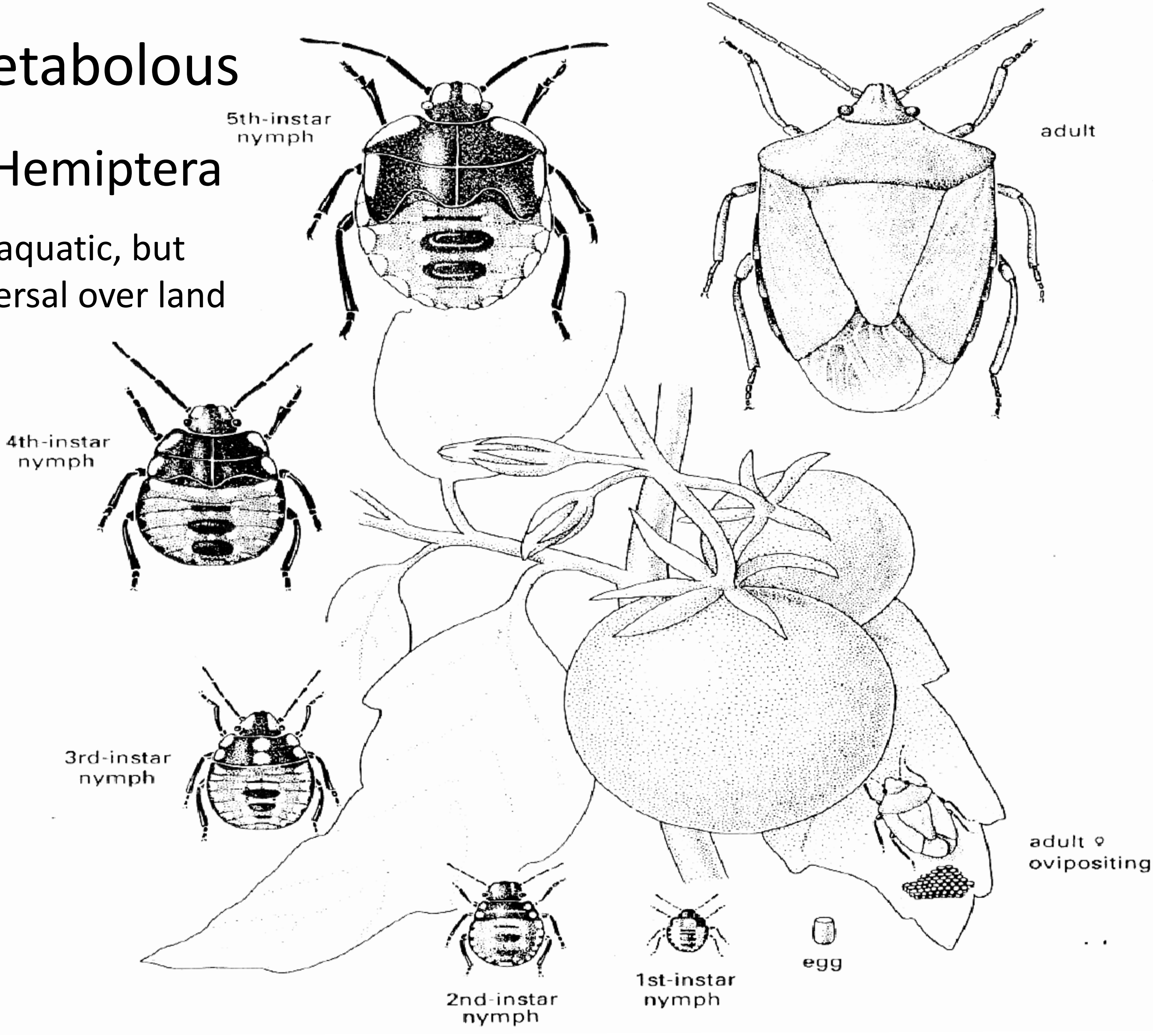


STROUD WATER RESEARCH CENTER

Paurometabolous

Aquatic Hemiptera

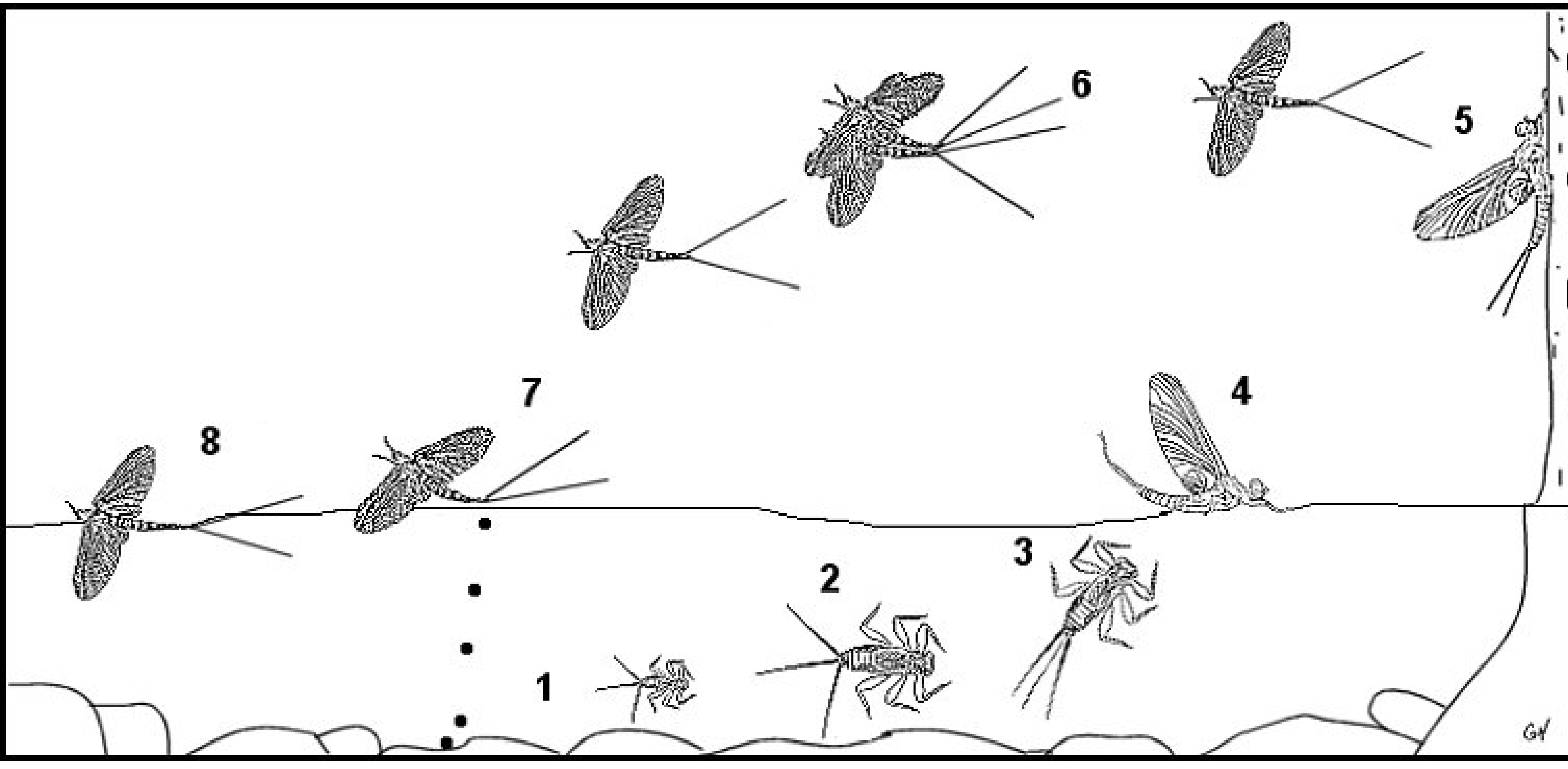
Primarily aquatic, but winged dispersal over land



Hemimetabolous development

Egg ➔ Larva ➔ Adult

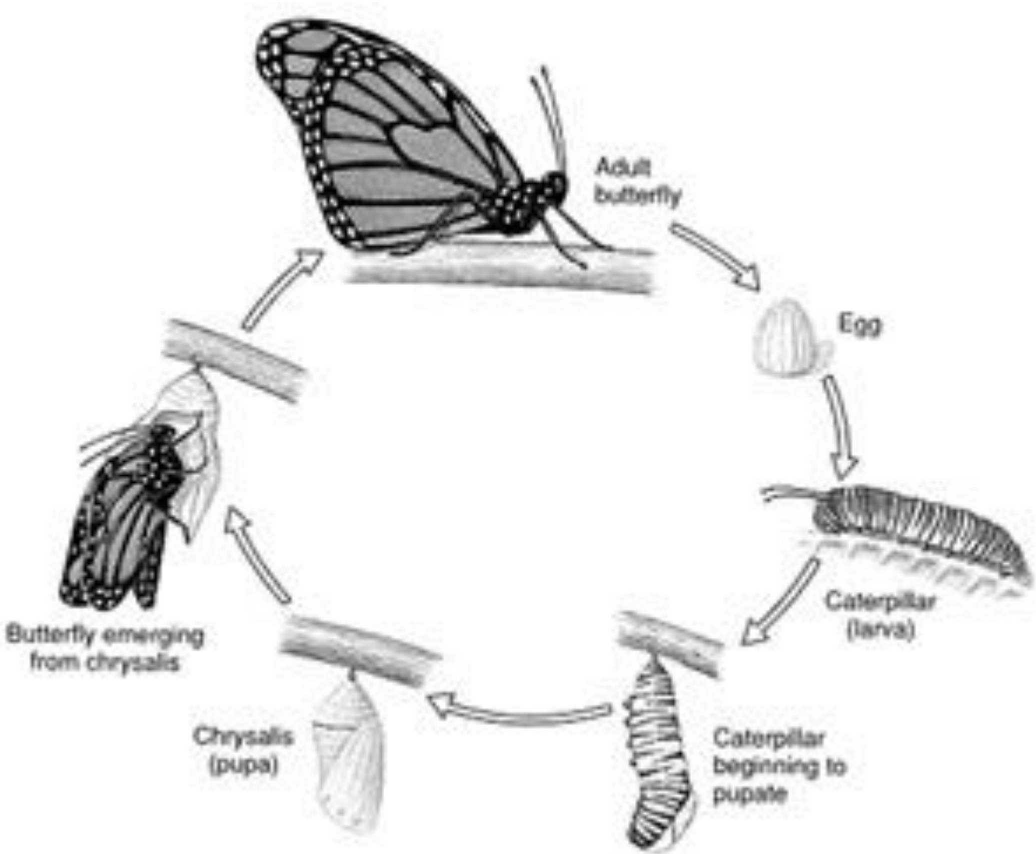
Aquatic ➔ terrestrial ➔ aquatic



Holometabolous development

Egg ➔ Larva ➔ Pupa ➔ Adult

Monarch Butterfly



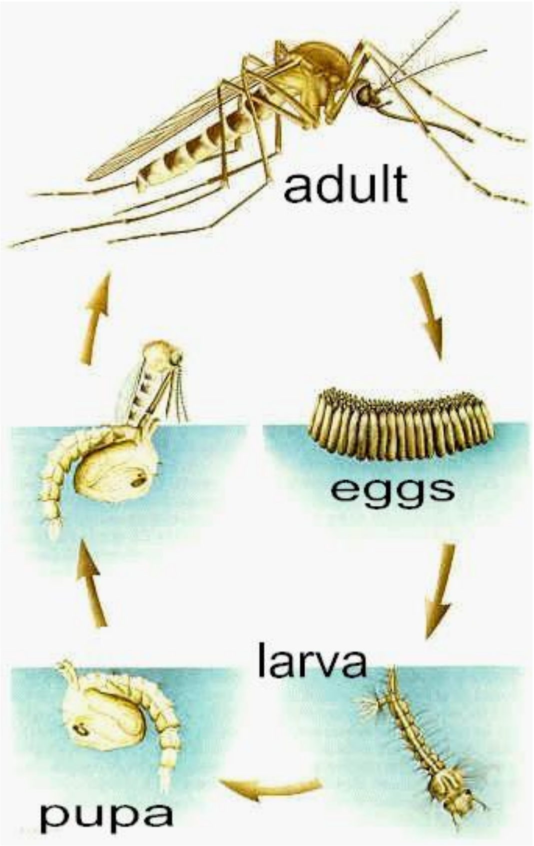
STROUD
WATER RESEARCH CENTER

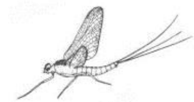
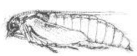
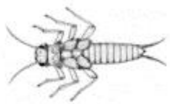
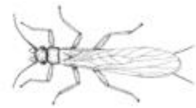
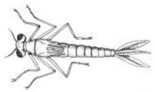
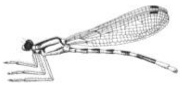
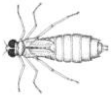
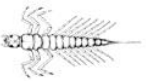
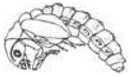
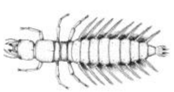
Holometabolous development

Egg ➔ Larva ➔ Pupa ➔ Adult

Aquatic ➔ terrestrial ➔ aquatic

Mosquito



Insect	Larval Stage	Pupal Stage	Adult Stage
Mayfly Ephemeroptera			
Caddisfly Trichoptera			
Stonefly Plecoptera			
True Fly Diptera			
Damselfly Odonata			
Dragonfly Odonata			
Moth Lepidoptera			
Alderfly Megaloptera			
Dobsonfly Megaloptera			

STROUD™
WATER RESEARCH CENTER

Questions that I will address today:

1) Why do I study aquatic macroinvertebrates?
2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?
3) How have insects adapted to life in water?
4) Are aquatic invertebrate populations dynamic variable over time?
5) What determines species richness and diversity – aquatic or terrestrial?

STROUD™ WATER RESEARCH CENTER

What are aquatic insects?

- Insects that have some connection with the water, either as eggs, immatures, pupae, or adults
- 3% of all insects are associated with freshwater and 0.1 % are associated with marine habitats
- **Adaptations to life in water**
  - Physiological
    - osmoregulate, ventilation
  - Morphological
    - obtain O_2, endure current, move in water, collect food
  - Behavioral
    - obtain O_2, ventilation

STROUD
WATER RESEARCH CENTER

O_2 in Aquatic Systems

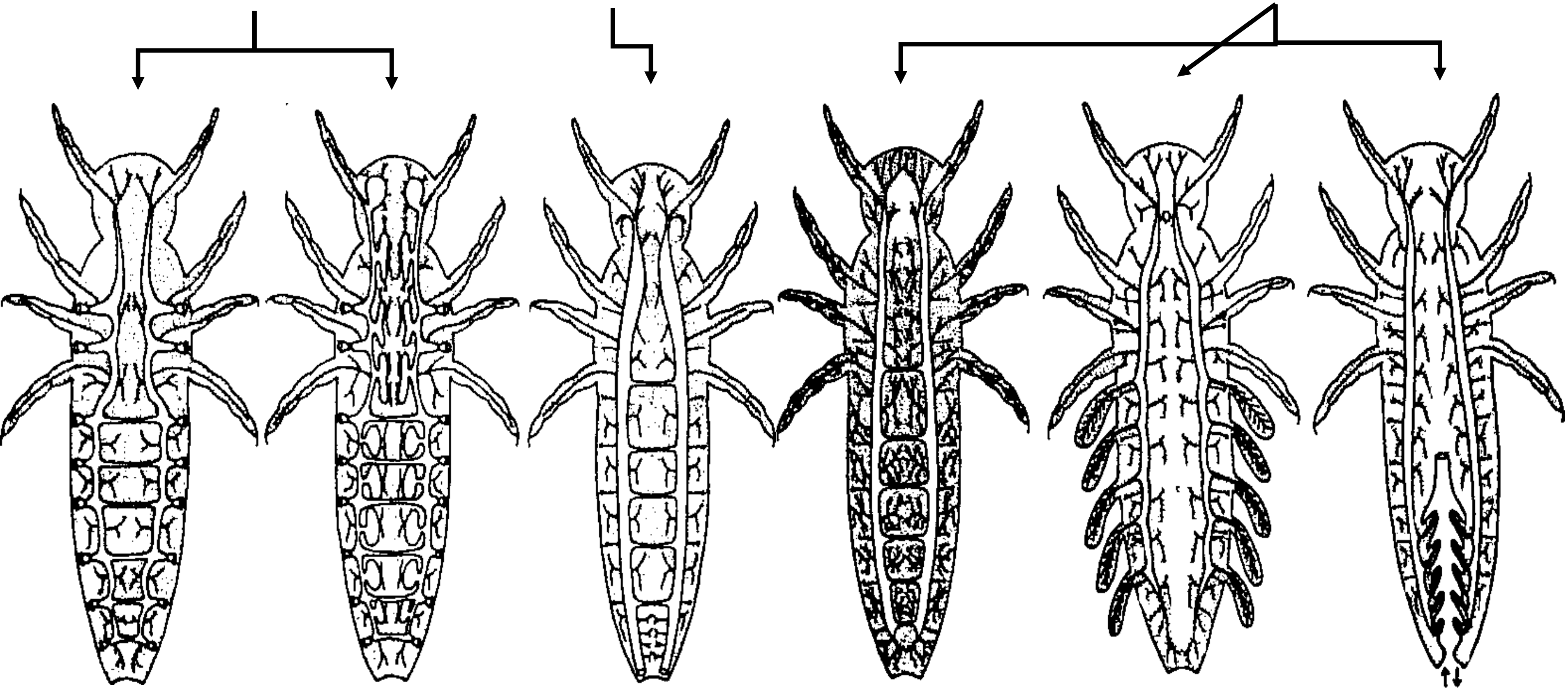
- O_2 in Aquatic habitats << Terrestrial
- O_2 in Aquatic habitats highly variable (anaerobic)
- Insects developed gas-filled (tracheal) respiratory system on land and then invaded water
- Several adaptations occurred to exploit O_2 in aquatic environments

The Tracheal System (open vs closed)

Polypneustic
8-10 pair spiracles

Oligopneustic
1-2 pair spiracles

Apneustic
No spiracles (closed system)



Open

Open
w/ air sacs

Terminal
spiracles

Cutaneous
respiration

Abdominal
tracheal
gills

Rectal
tracheal
gills

Closed Respiratory Systems - obtaining O_2 from H_20

- <u>**No spiracles –** most of our common aquatic insects</u>
- <u>**Cutaneous respiration**</u>
  - Direct diffusion across the body surface
    - As size increases, the surface area to body mass ratio decreases and there is need for additional surface area
    - Additional gas exchange surfaces or *gills* - large, thin, tracheated body evaginations
  - Often thought that only small insects used this, but may actually be great in some larger insects

STROUD™ WATER RESEARCH CENTER

No spiracles, yet gas-filled trachea

Simuliidae
(Diptera)

Chaoborus
(Diptera)

STROUD WATER RESEARCH CENTER

Aquatic respiratory options - obtaining O_2 from H_20

- **Tracheal gills**-body wall evaginations of abdominal, thoracic, cephalic (head), and rectal (internal)
  - Ephemeroptera (mayflies)
  - Odonata (dragonflies)
  - Plecoptera (stoneflies)
  - Megaloptera (hellgramites)
  - Coleoptera (several beetle families)
  - Diptera (several fly families)
  - Trichoptera (caddisflies)
  - Lepidoptera (moths)

STROUD™ WATER RESEARCH CENTER

Sialis sp. (Megaloptera)

Zygoptera (Odonata)

Anisoptera (Odonata)

Perla sp. (Plecoptera)

Cloeon sp. (Ephemeroptera)

Ephemera danica (Ephemeroptera)

Potamanthus sp.
(Ephemeroptera)

Rhithrogena sp.
(Ephemeroptera)

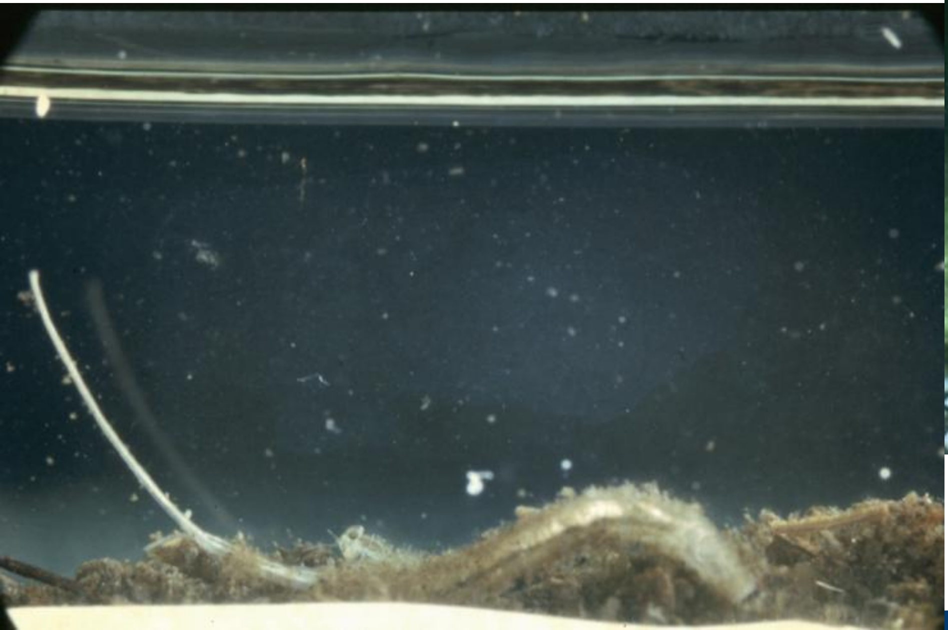
Open Respiratory Systems

Stroud Water Research Center

- Respiratory siphon – tube
  - Hydrofuge hairs - To break water surface
  - Piercers - to penetrate plant

Ranatra linearis (Hemiptera)

Nepa rubra (Hemiptera)

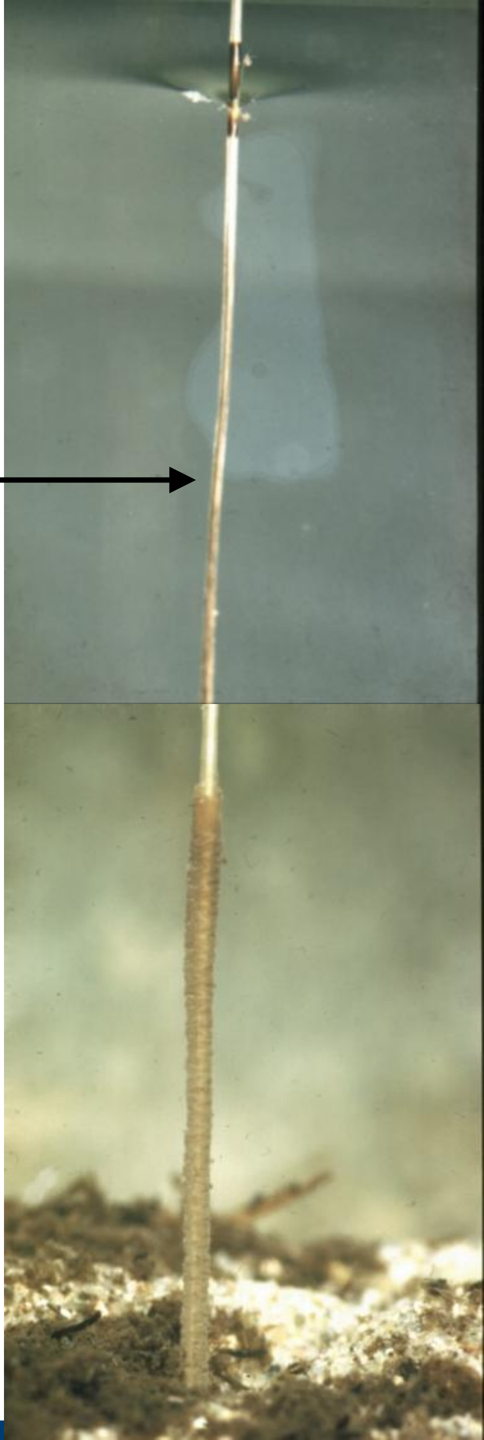


Tychoptera (Diptera)

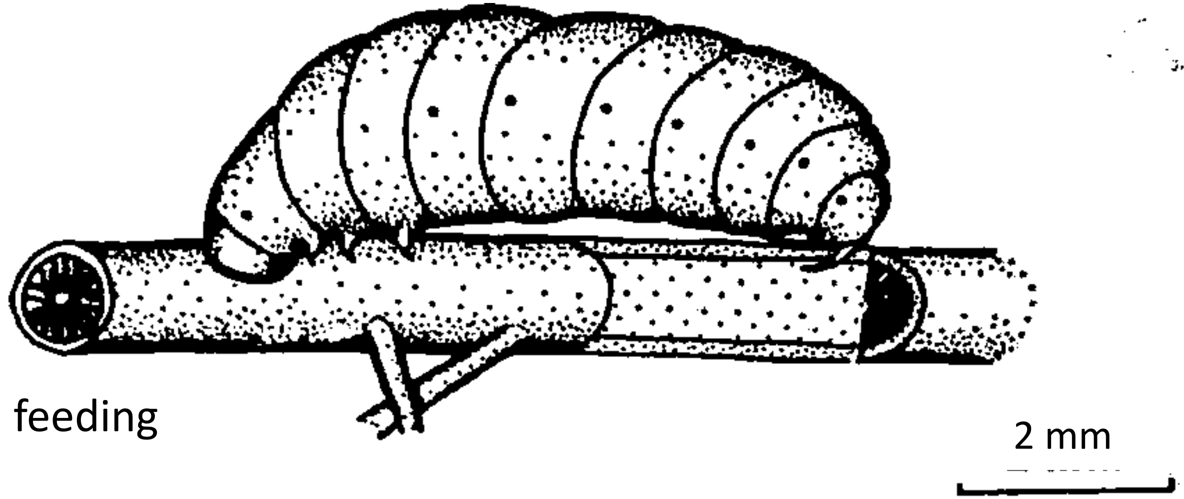
STROUD WATER RESEARCH CENTER

Eristalis sp. (Diptera: Syrphidae)
"Rat-tailed maggot"

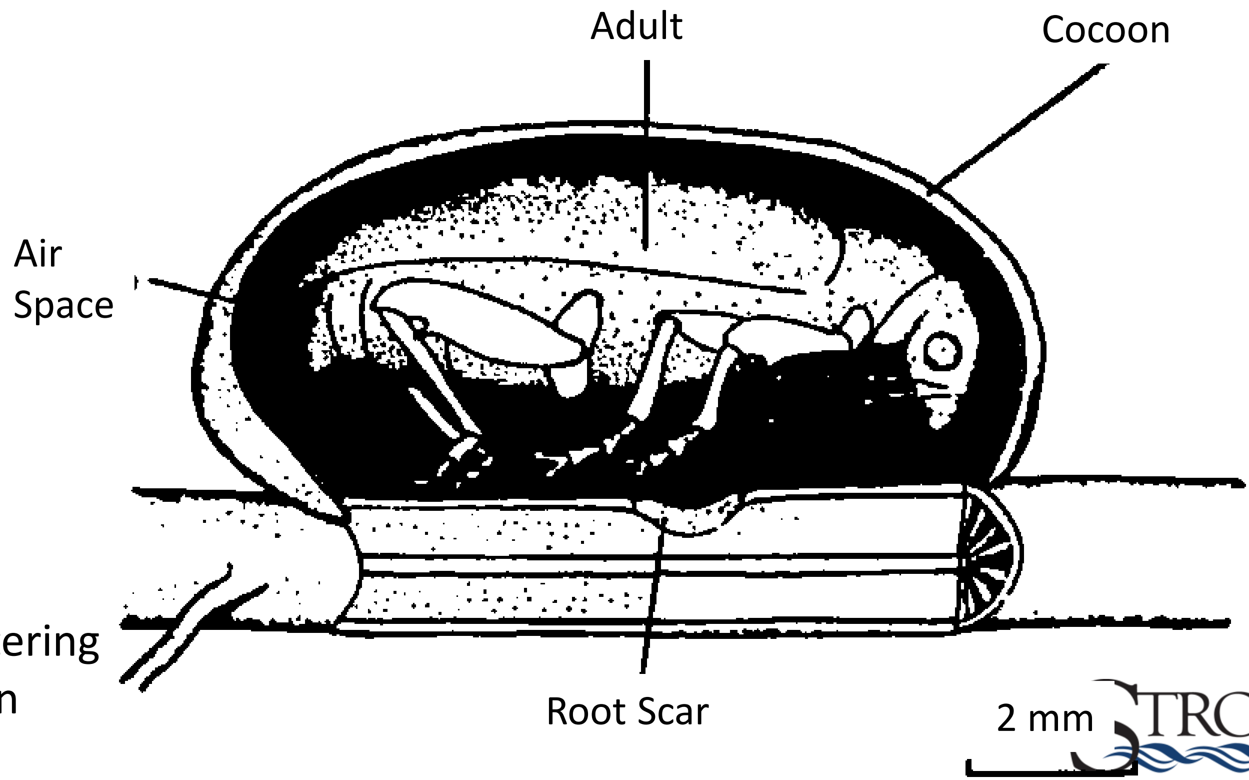
Telescoping respiratory siphon extends to 6x body length



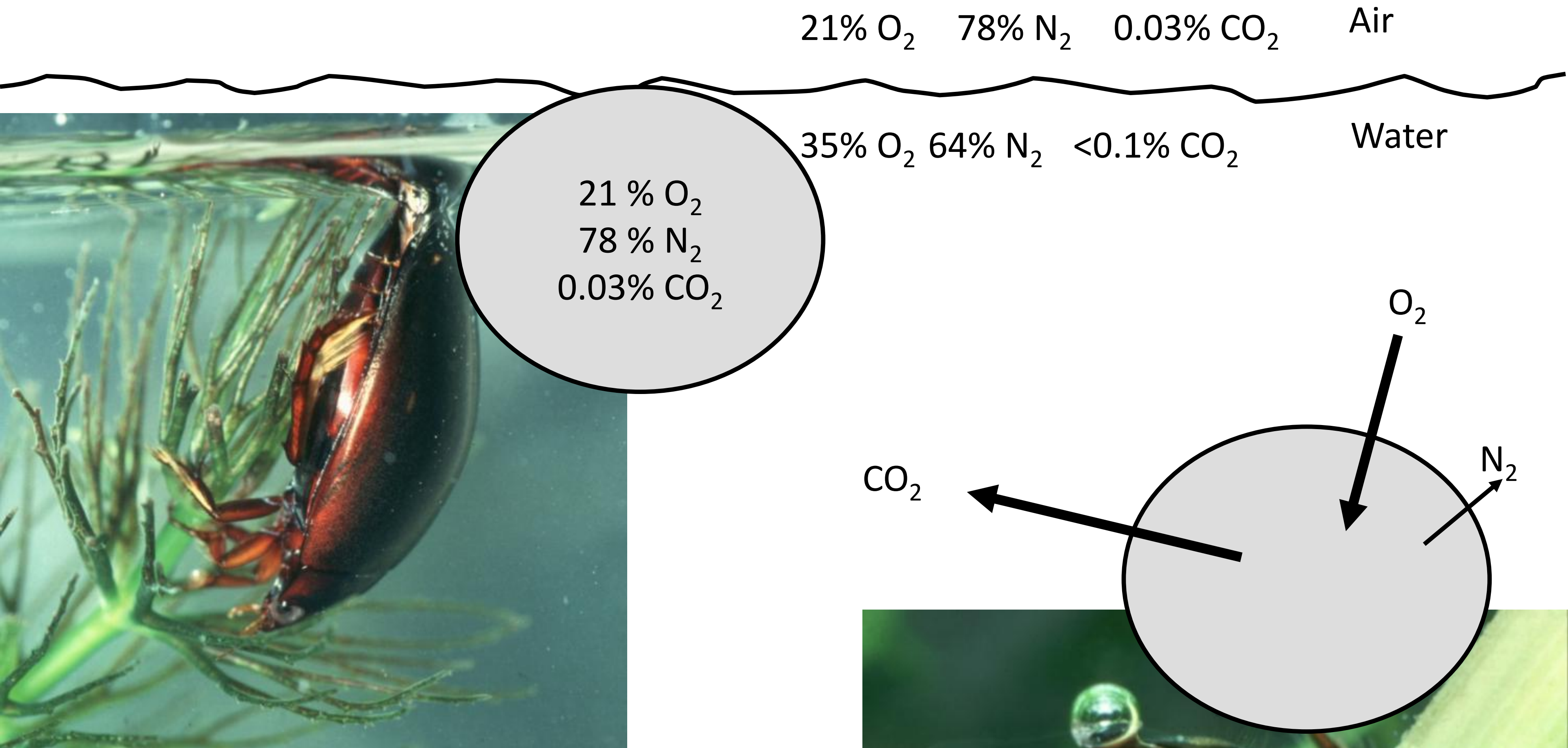
Chrysomelidae
(Coleoptera)



Larvae piercing
plant root while feeding

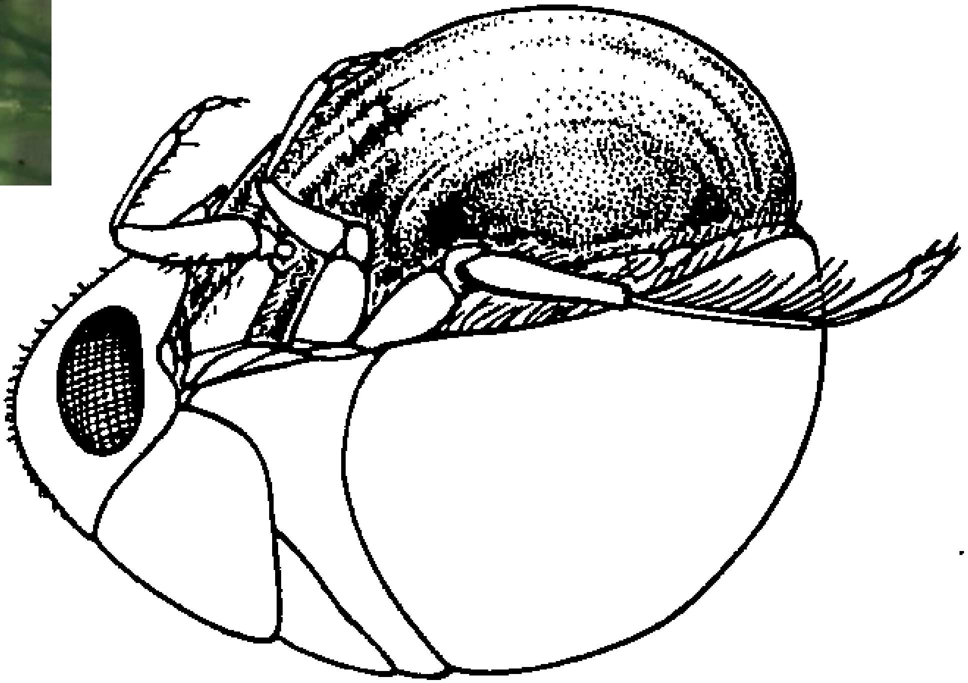


Adult over-wintering
in pupae cocoon



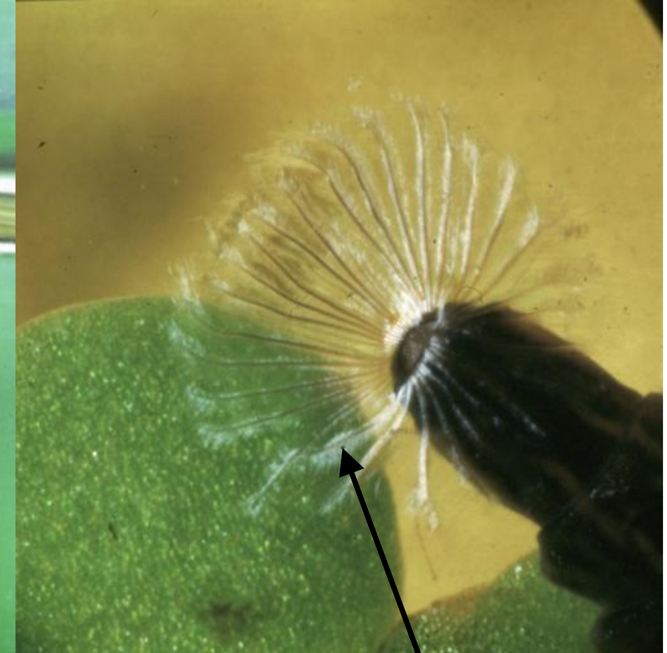
The Physical Gill

Notonectidae
(Hemiptera)



Neoplea (Hemiptera)
with air bubble

STROUD WATER RESEARCH CENTER



Hydrofuge hairs

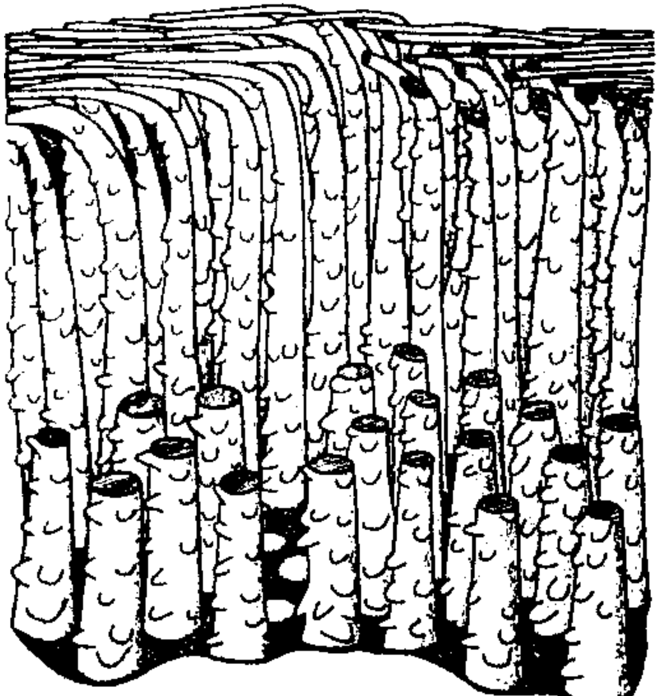
Stratiomyidae (Diptera)

STROUD
WATER RESEARCH CENTER

Aphelocheirus
(Hemiptera)

Elmidae
(Coleoptera)

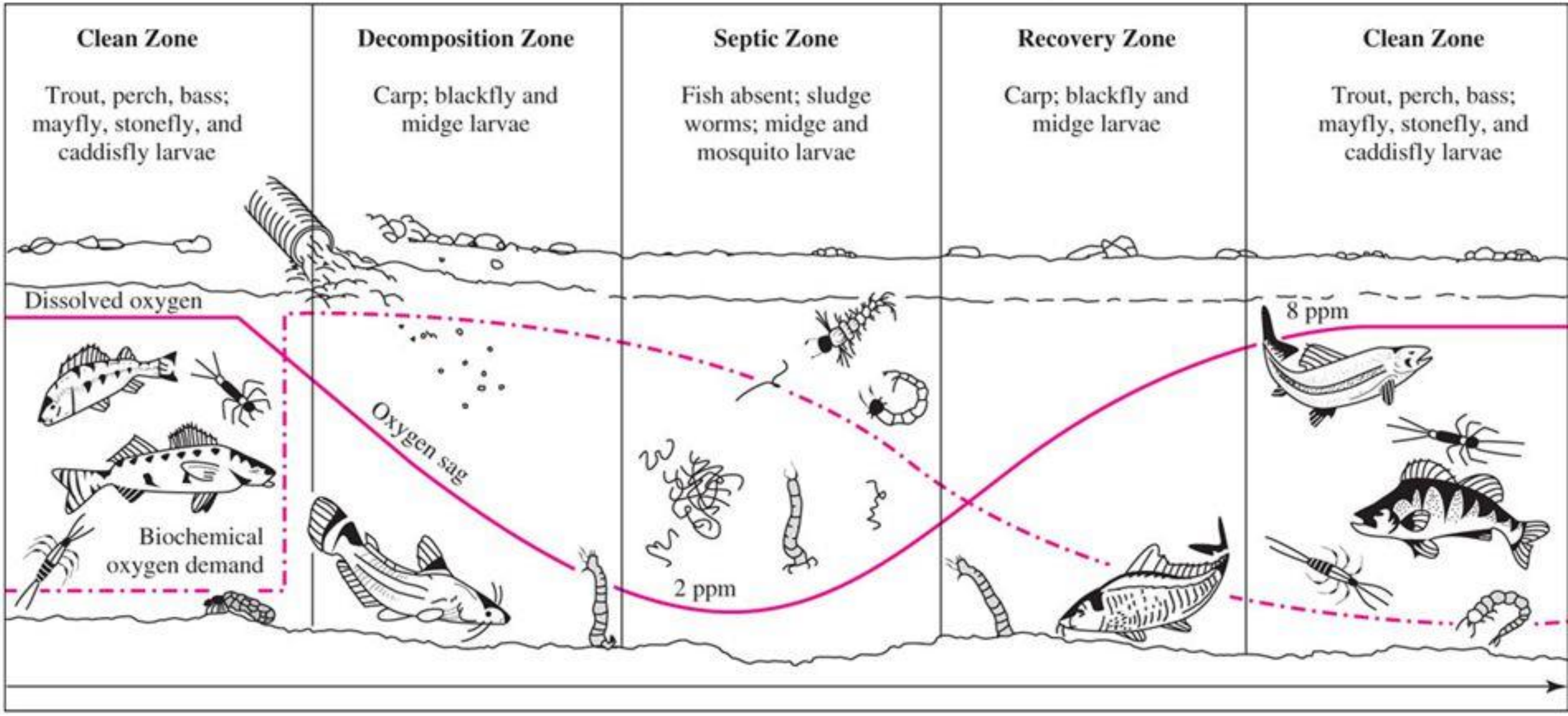
Plastron = permanent physical gill



Hydrofuge hairs of the **plastron**

DO Sag Curves

Common pre-Clean Water Act
Not common now

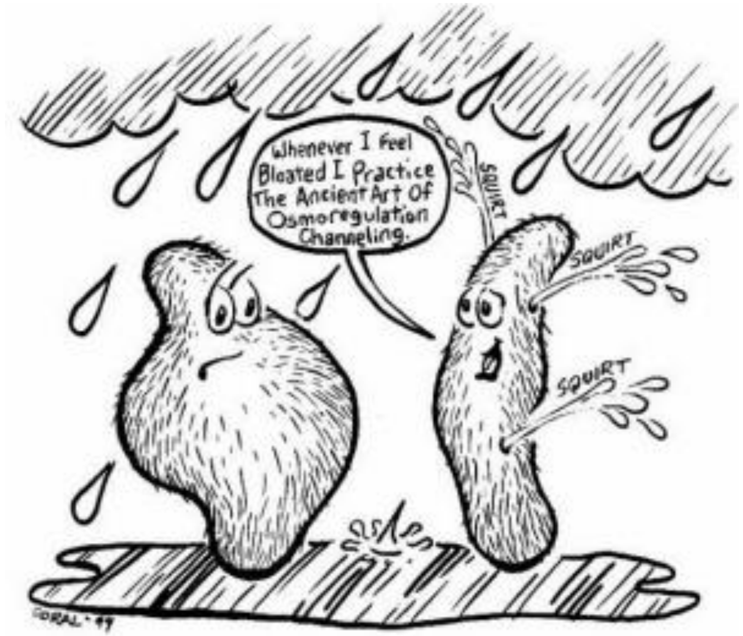


Osmoregulation

- Insect’s waxy cuticle is primary barrier to water & salt exchange

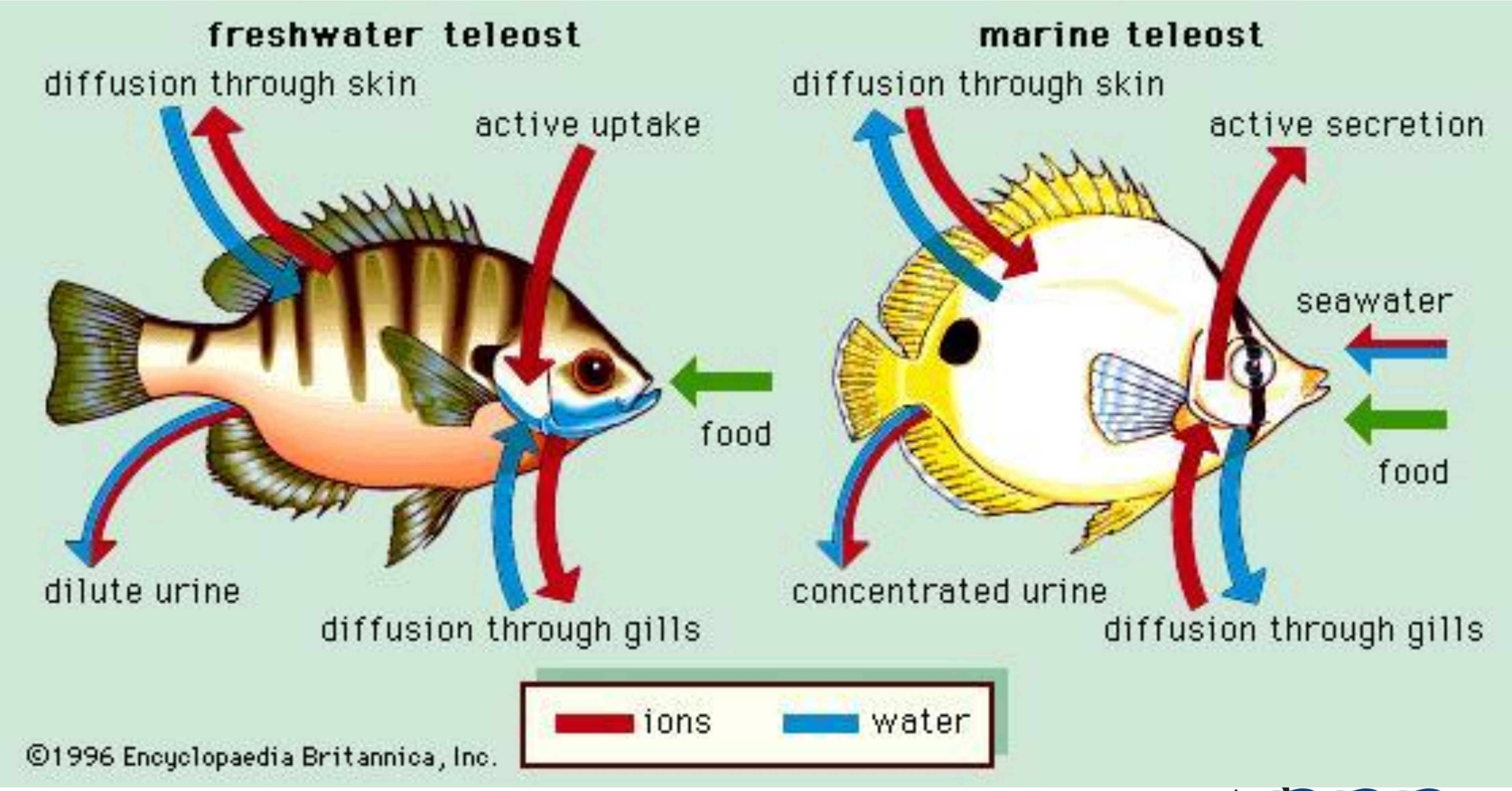
- In freshwater - body fluids are **hypertonic** to environment
  - water in, salts out due to concentration gradients
  - therefore, physiology needs to conserve salts, excrete dilute urine

- marine/brackish systems - body fluids are **hypotonic** to environment
  - water out, salts in due to concentration gradients
  - therefore, conserve water, excrete concentrated urine (salts)

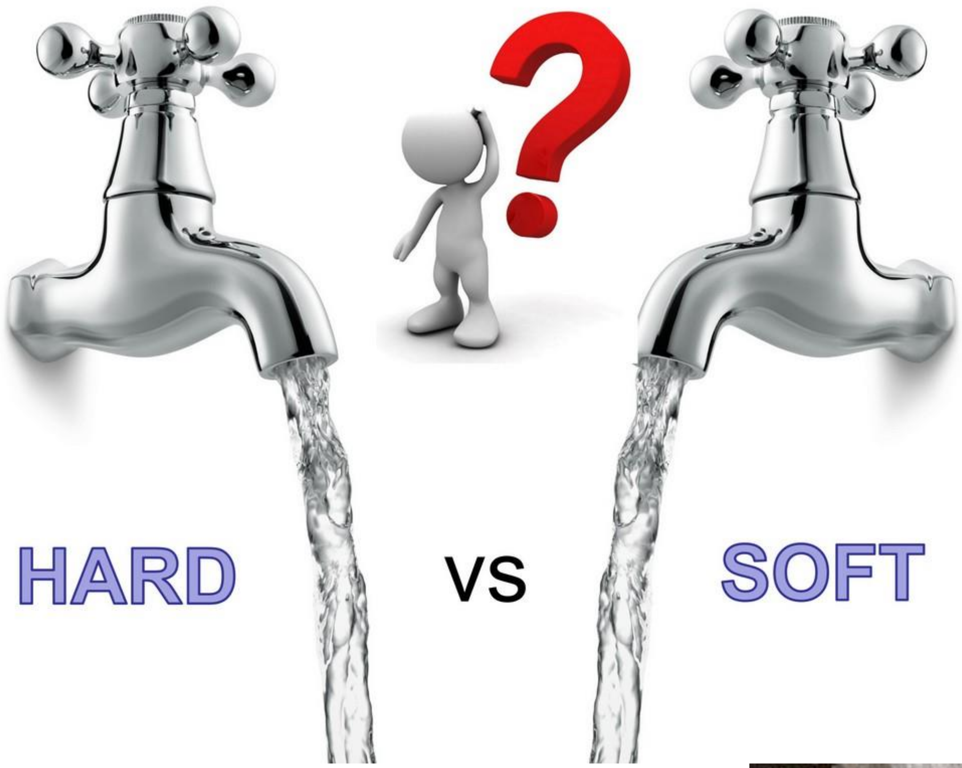


http://www.umanitoba.ca/faculties/afs/soil_science/MSSS/Ecology/Cartoons/Cartoons%20images/osmoregulation.jpg

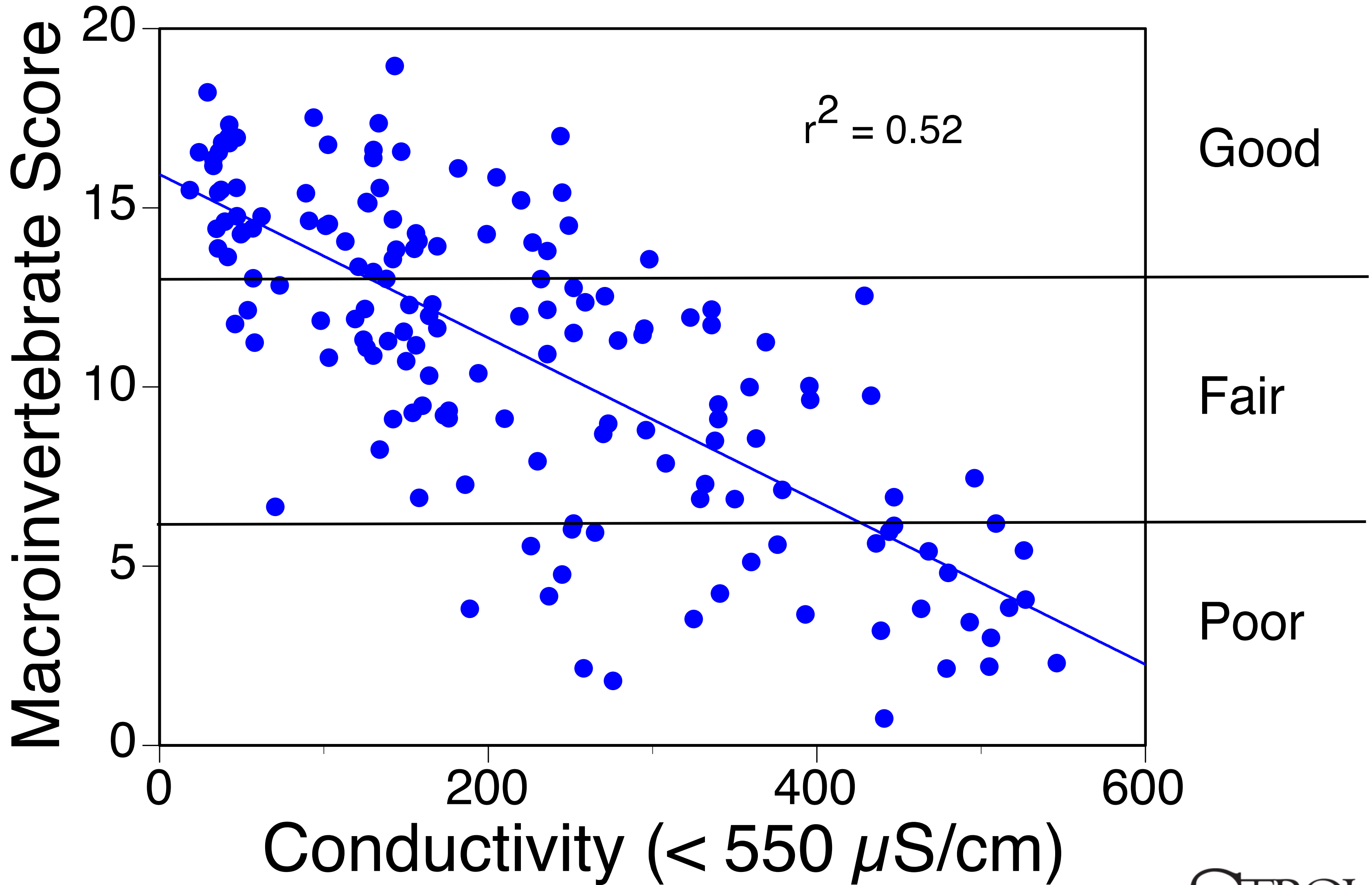
Osmoregulation



Osmoregulation

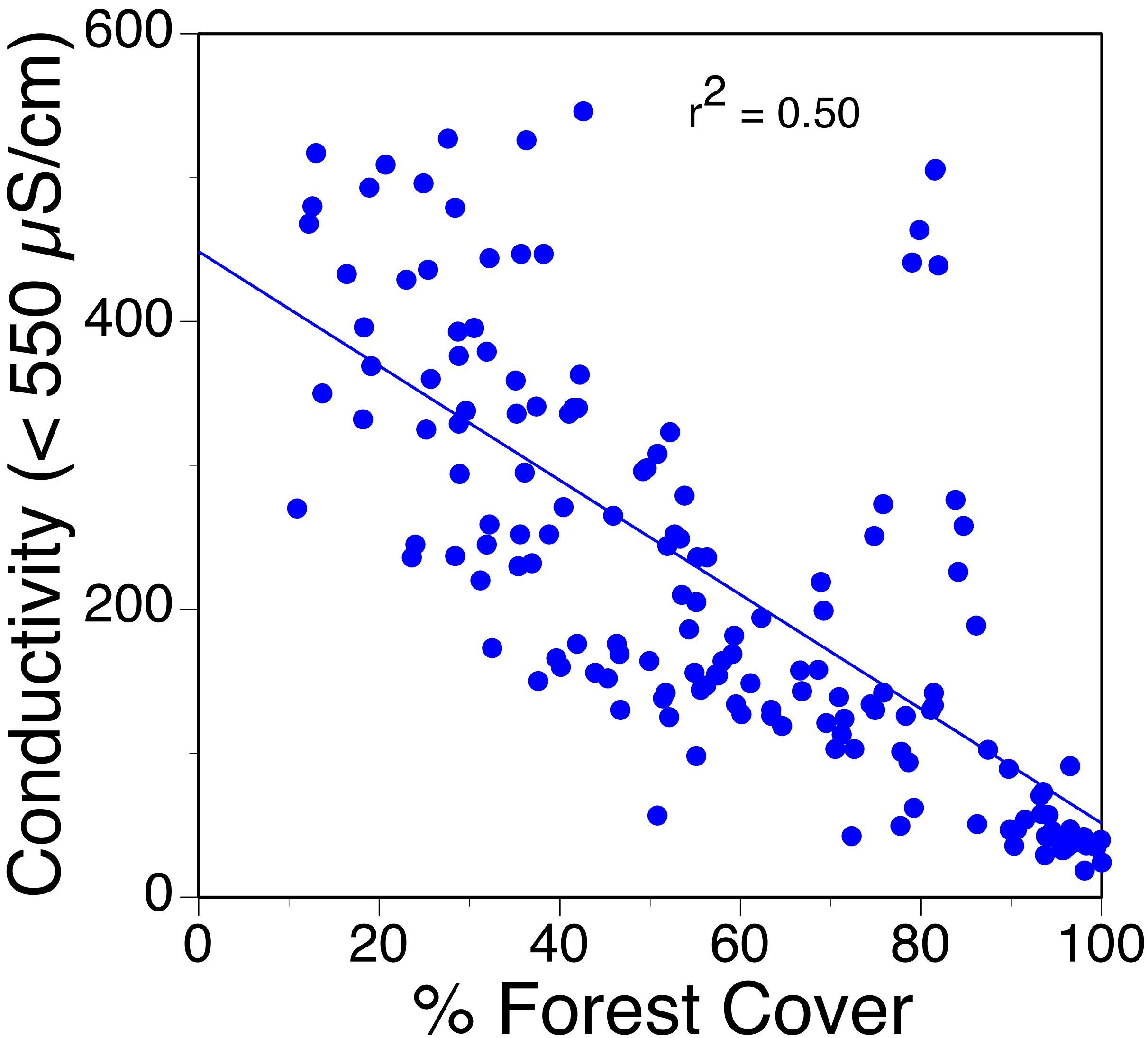


157 sites, primarily in Schuylkill River basin



STROUD WATER RESEARCH CENTER

157 sites, primarily in Schuylkill River basin

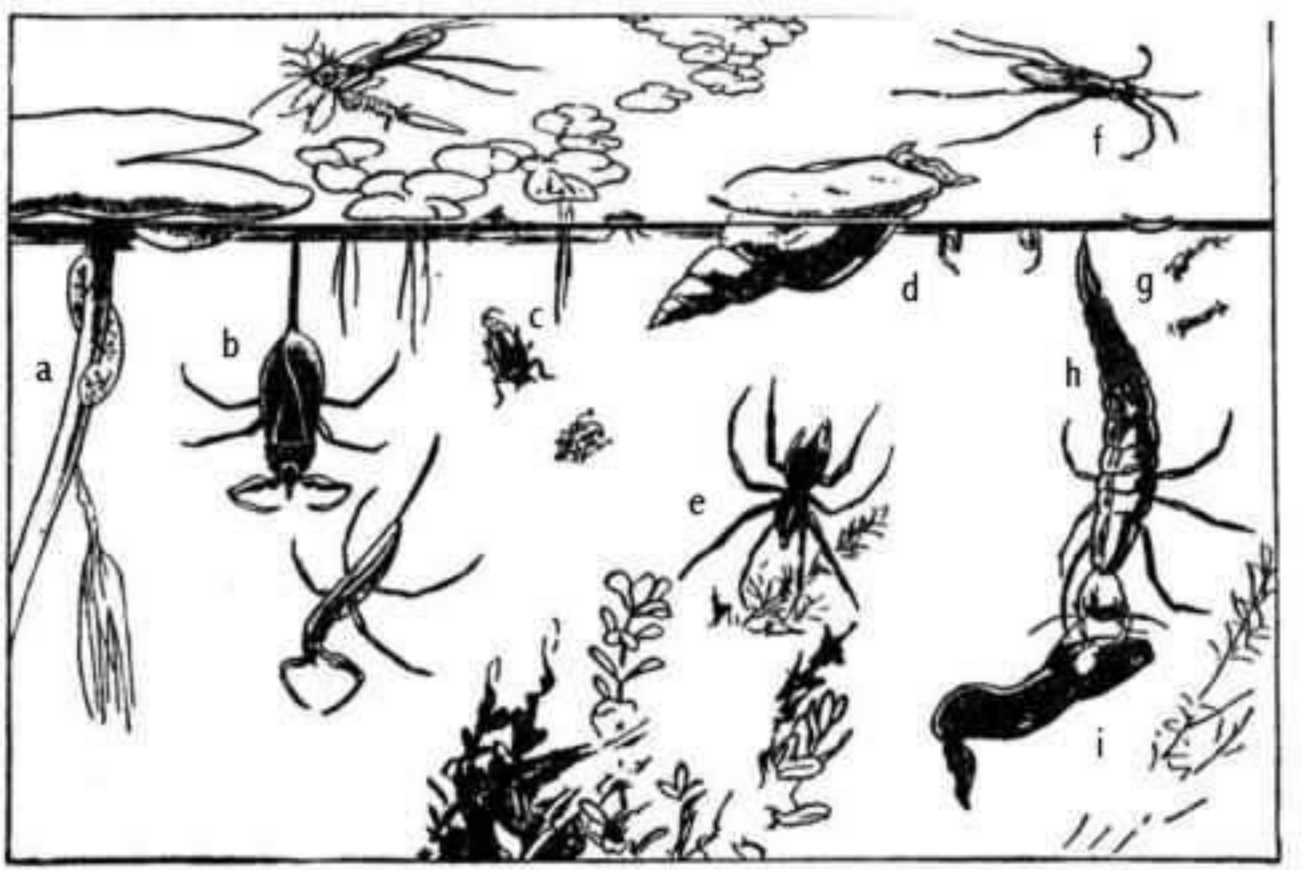


STROUD WATER RESEARCH CENTER

What are aquatic insects?

- Insects that have some connection with the water, either as eggs, immatures, pupae, or adults
- 3 % of all insects are associated with freshwater and 0.1 % are associated with marine habitats
- **Adaptations to life in water**
  - Physiological
    - osmoregulate, ventilation
  - Morphological
    - obtain O_2, endure current, move in water, collect food
  - Behavioral
    - obtain O_2, ventilation

STROUD™
WATER RESEARCH CENTER


a
b
c
d
e
f
g
h
i

Clingers

Climbers

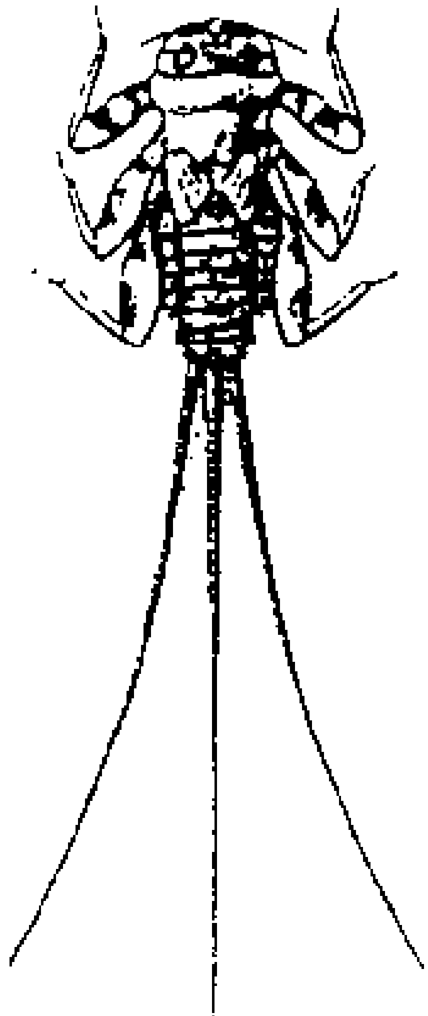
Crawlers

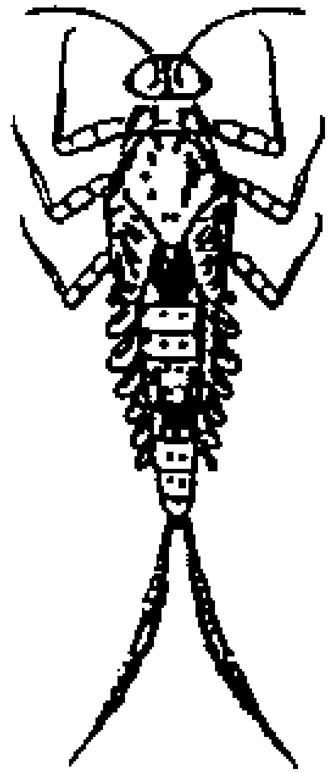
Sprawlers

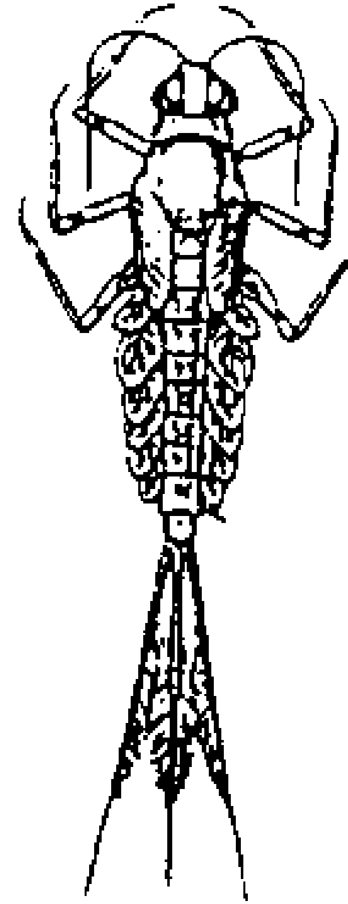
Burrowers

Swimmers

Skaters







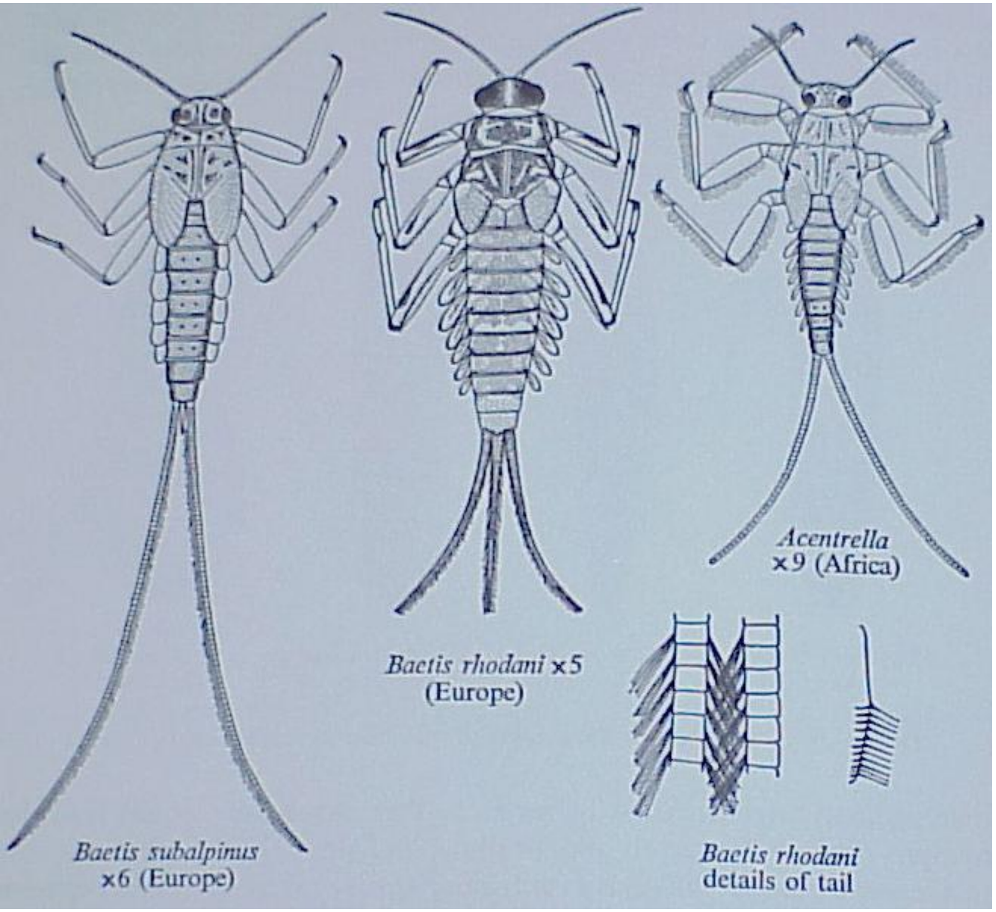
Moving in water or avoiding moving water (current)

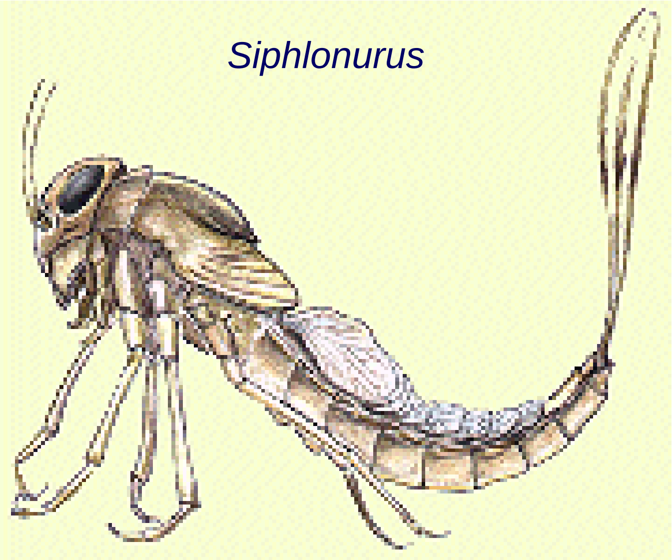
- **swimming appendages** - *Notonecta*, corixid legs, *Ameletus* cerci form a fan
- **stream line body** - reduce drag when swimming
- **flatten** - reduce drag, also avoidance in cracks and crevices
- **feeding** - silk nets (net spinning caddisflies, midges) or feeding appendages (black flies, *Brachycentrus*) that exploit current

STROUD™ WATER RESEARCH CENTER

Swimmers

Streamlined bodies & swim hairs. Cling to submerged stones or plants and usually swim in short bursts

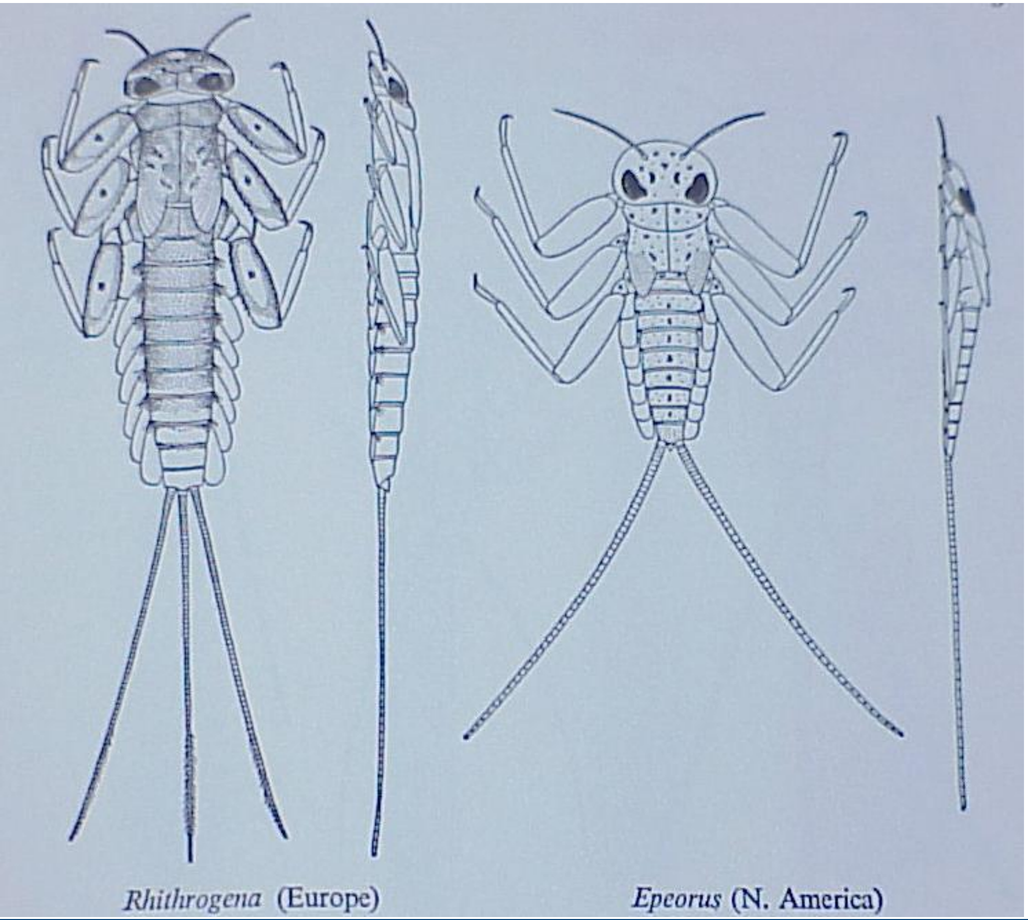




STROUD WATER RESEARCH CENTER

Clingers

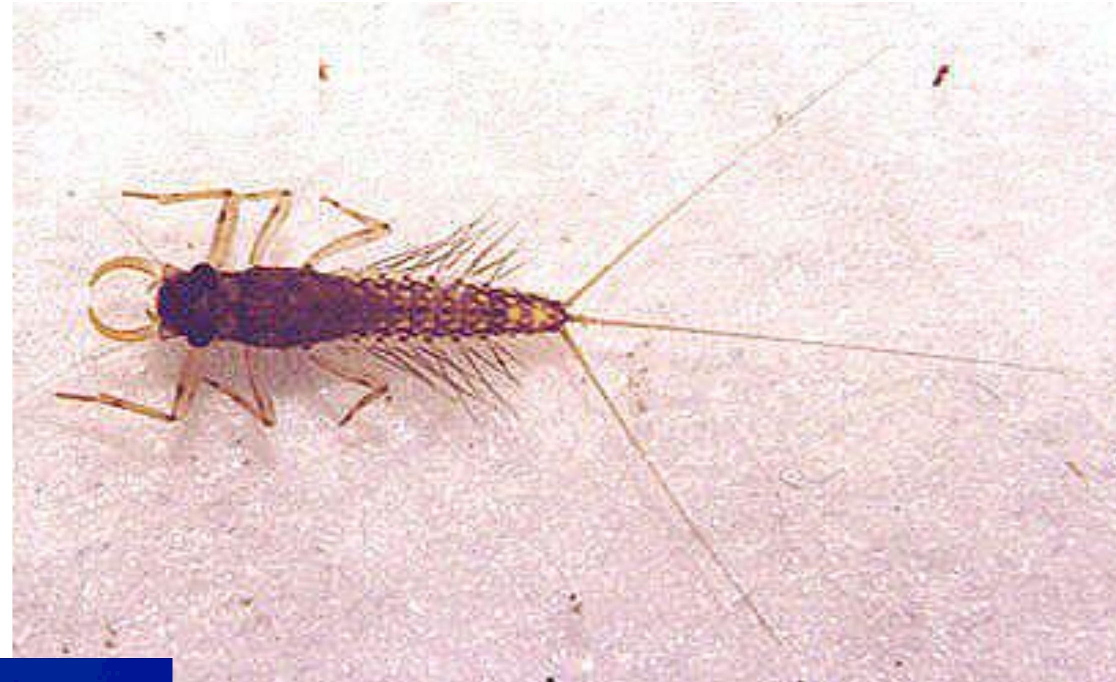
Large curved claws , dorsoventrally flattened, rheophilic, can swim if forced



Epeorus

Sprawlers

Poor swimmers,
avoid current,
prefer intersticies between substrate and detritus



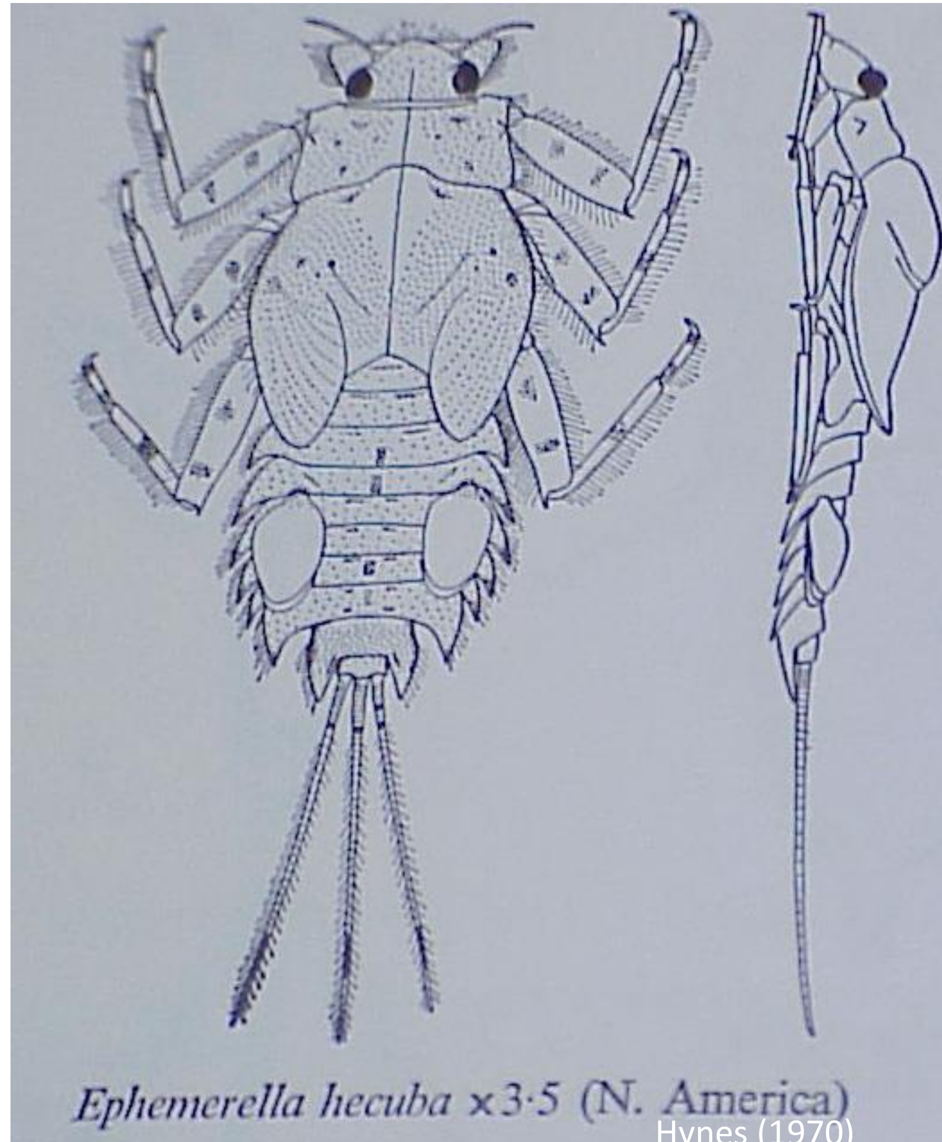
Paraleptophlebia

Potamantus luteus

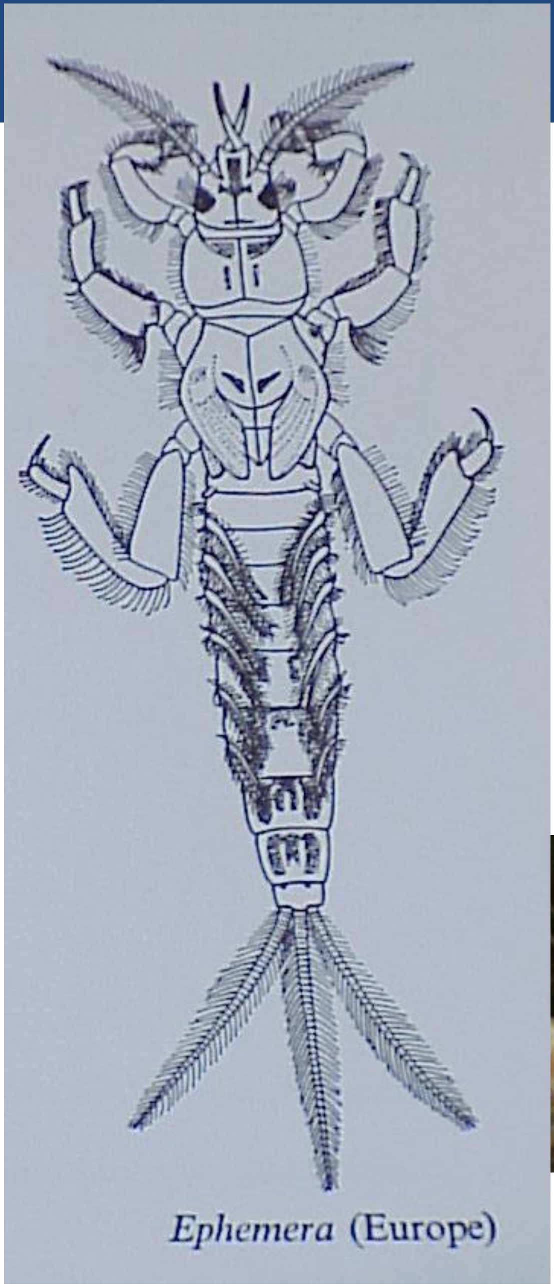
STROUD
WATER RESEARCH CENTER

Climbers

Poor swimmers, avoid current, prefer vegetation

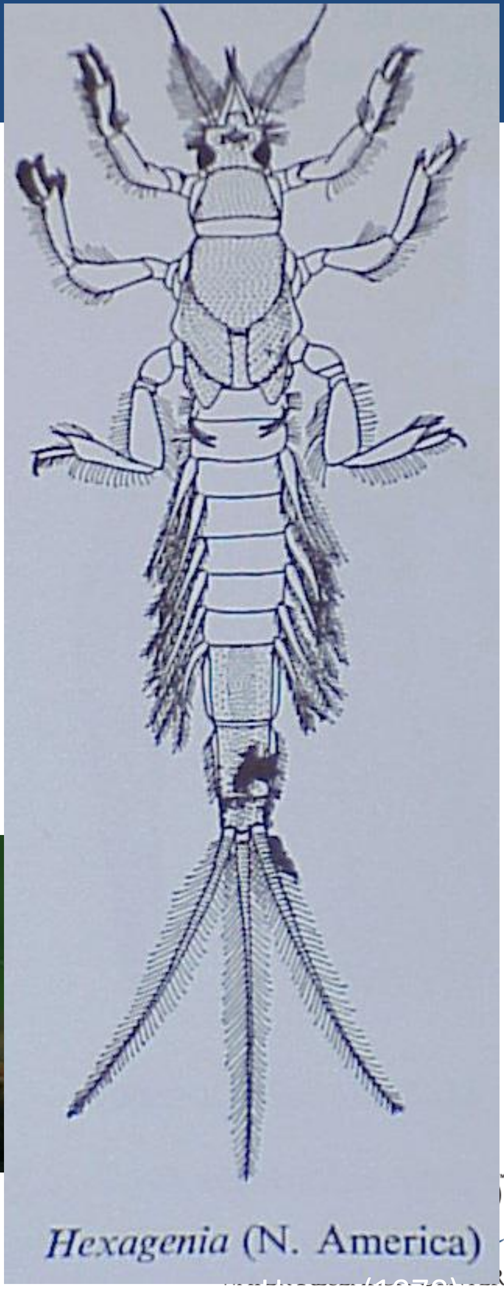


Burrowers

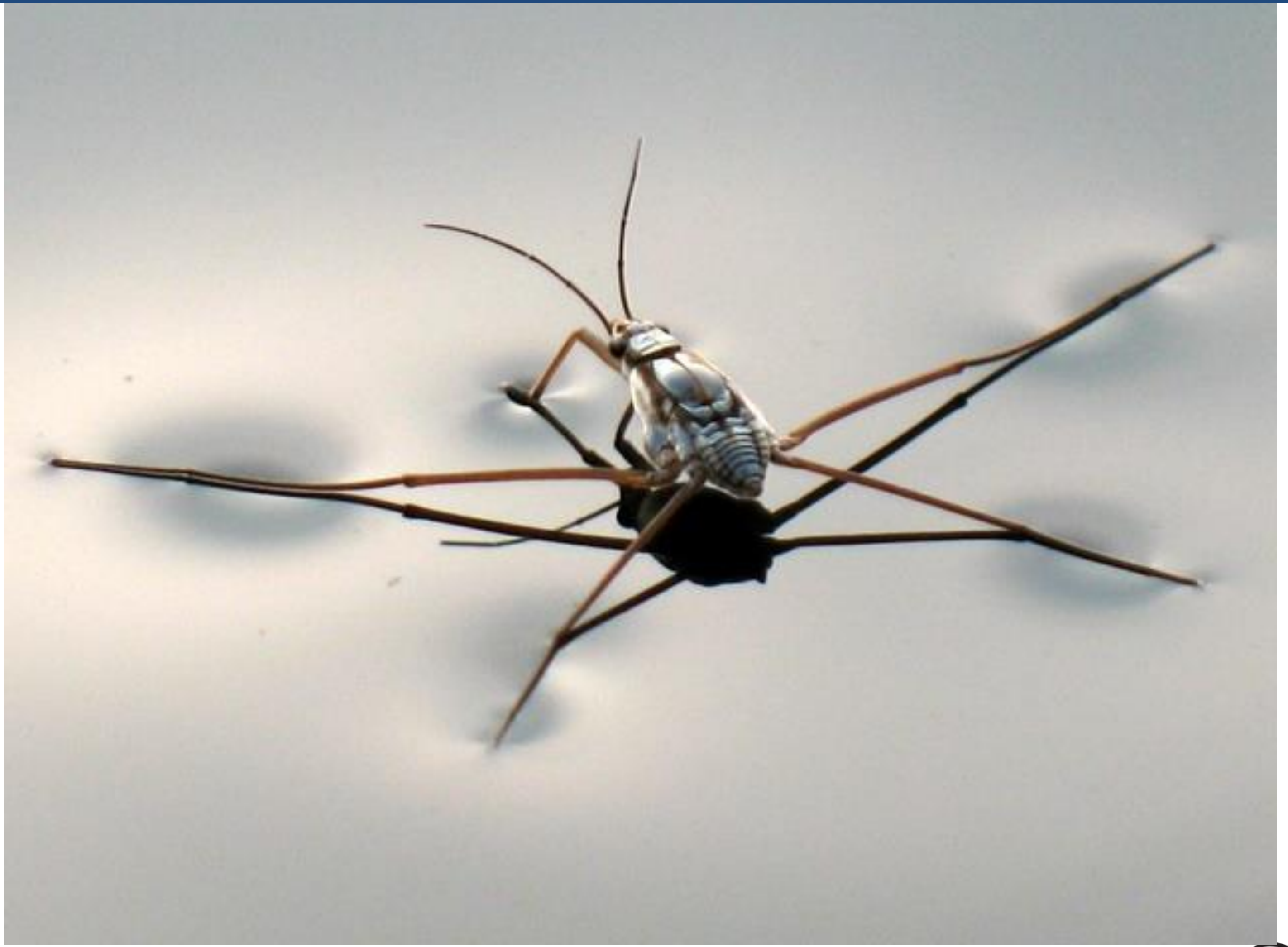


Prefer soft sediment, equipped with digging tusks, large bushy gills for O_2 poor conditions, lentic

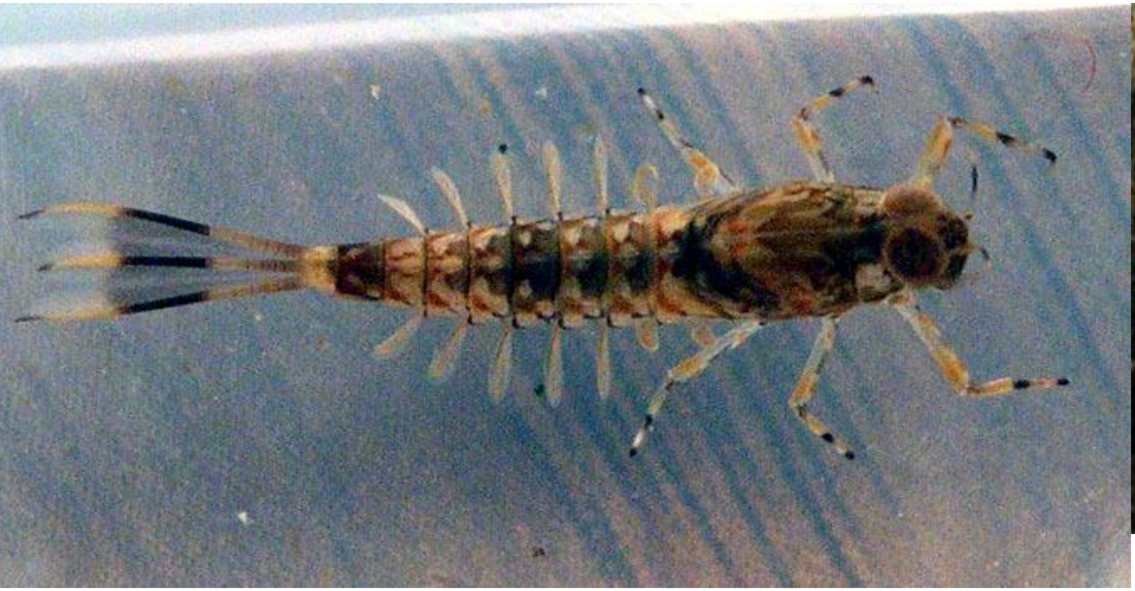
Ephemera danica



Skaters




Body form reflects habit and habitat



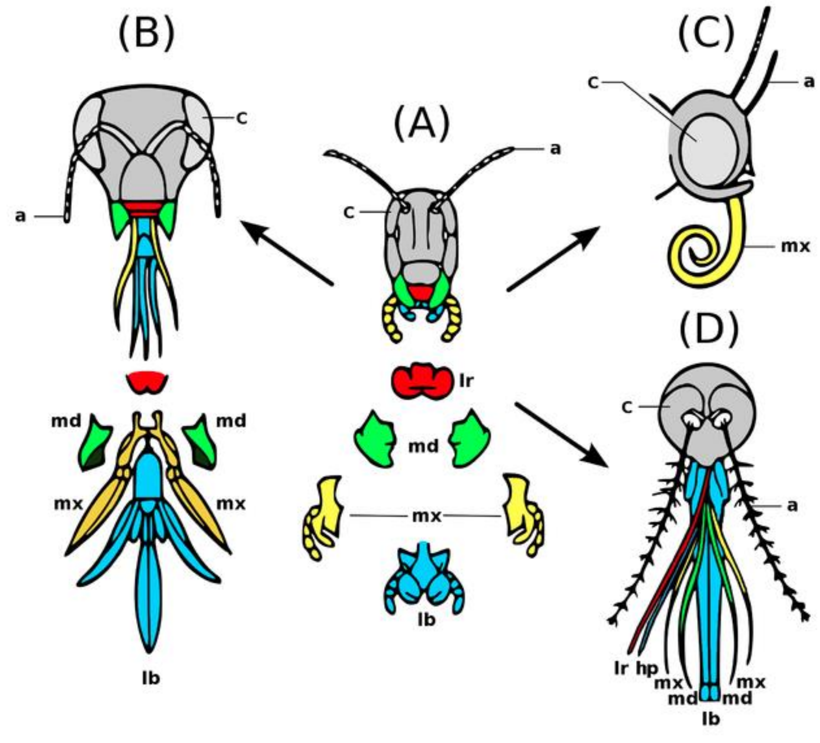

WATER RESEARCH CENTER

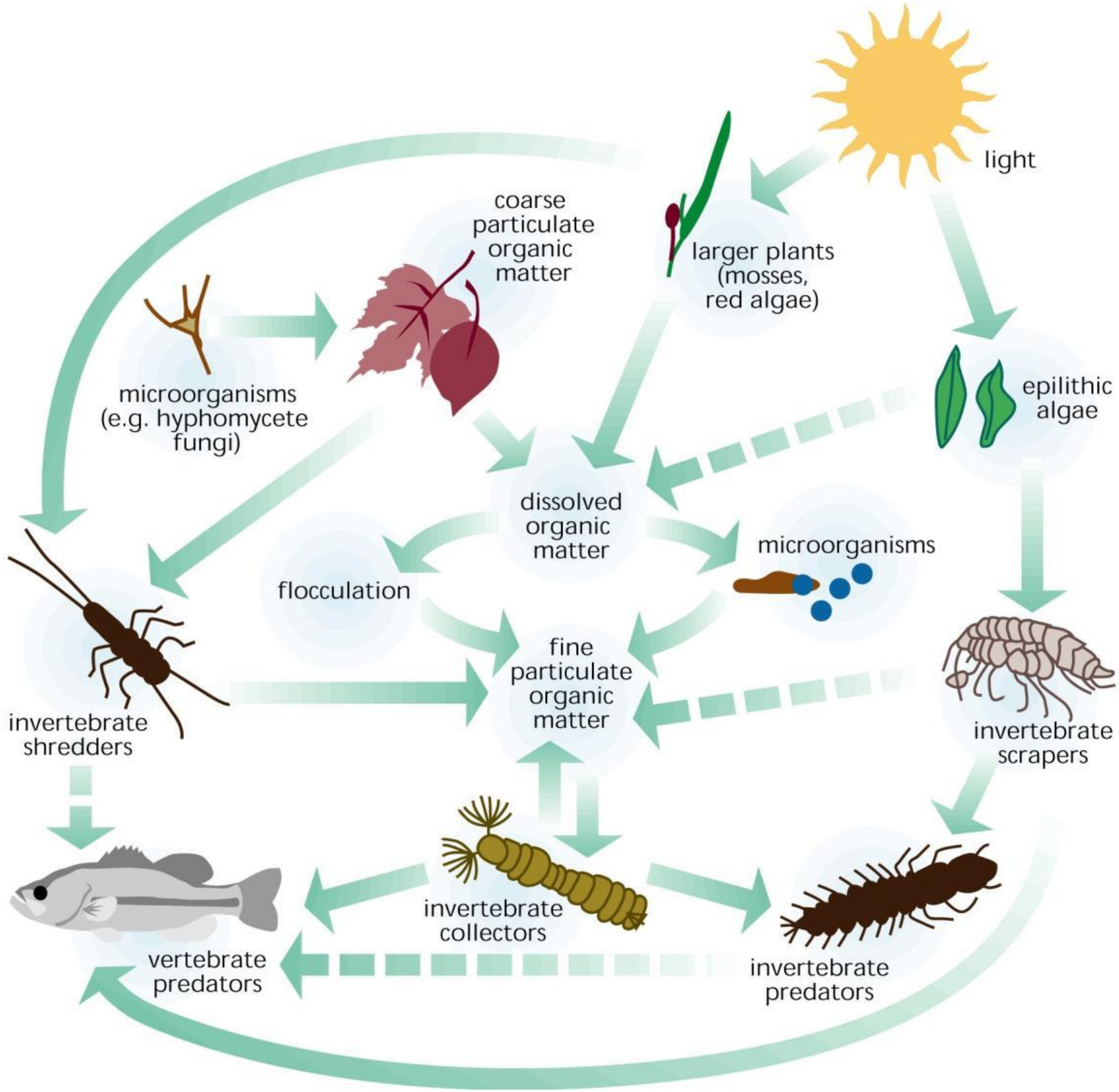
Feeding

Morphology and Behavior

Mouthparts

A – Chewing
B – Piercing
C – Siphoning
D – Lapping





STROUD™ WATER RESEARCH CENTER

Coarse organic particles ➔ **fine** organic particles & **dissolved** organic matter

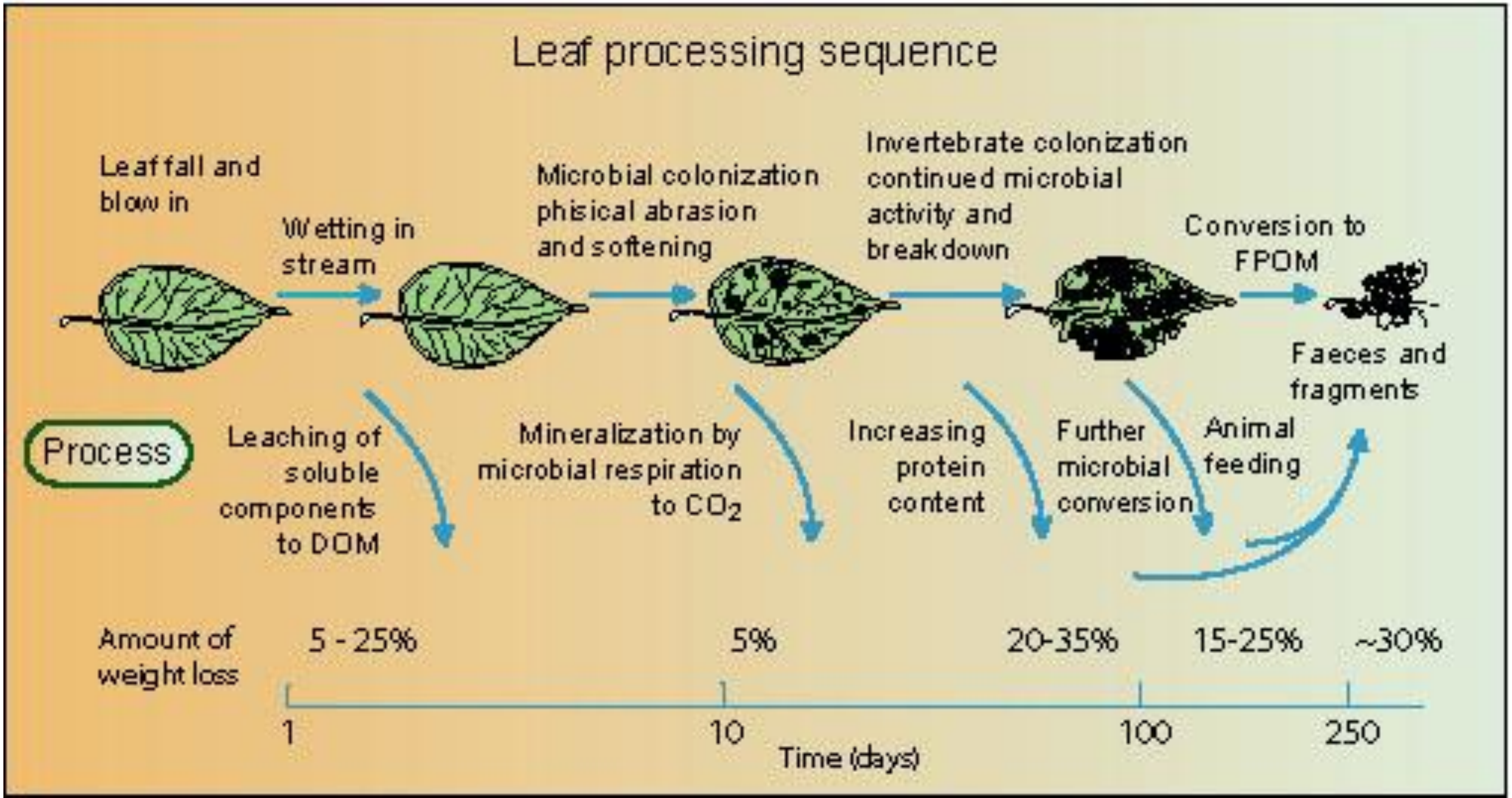
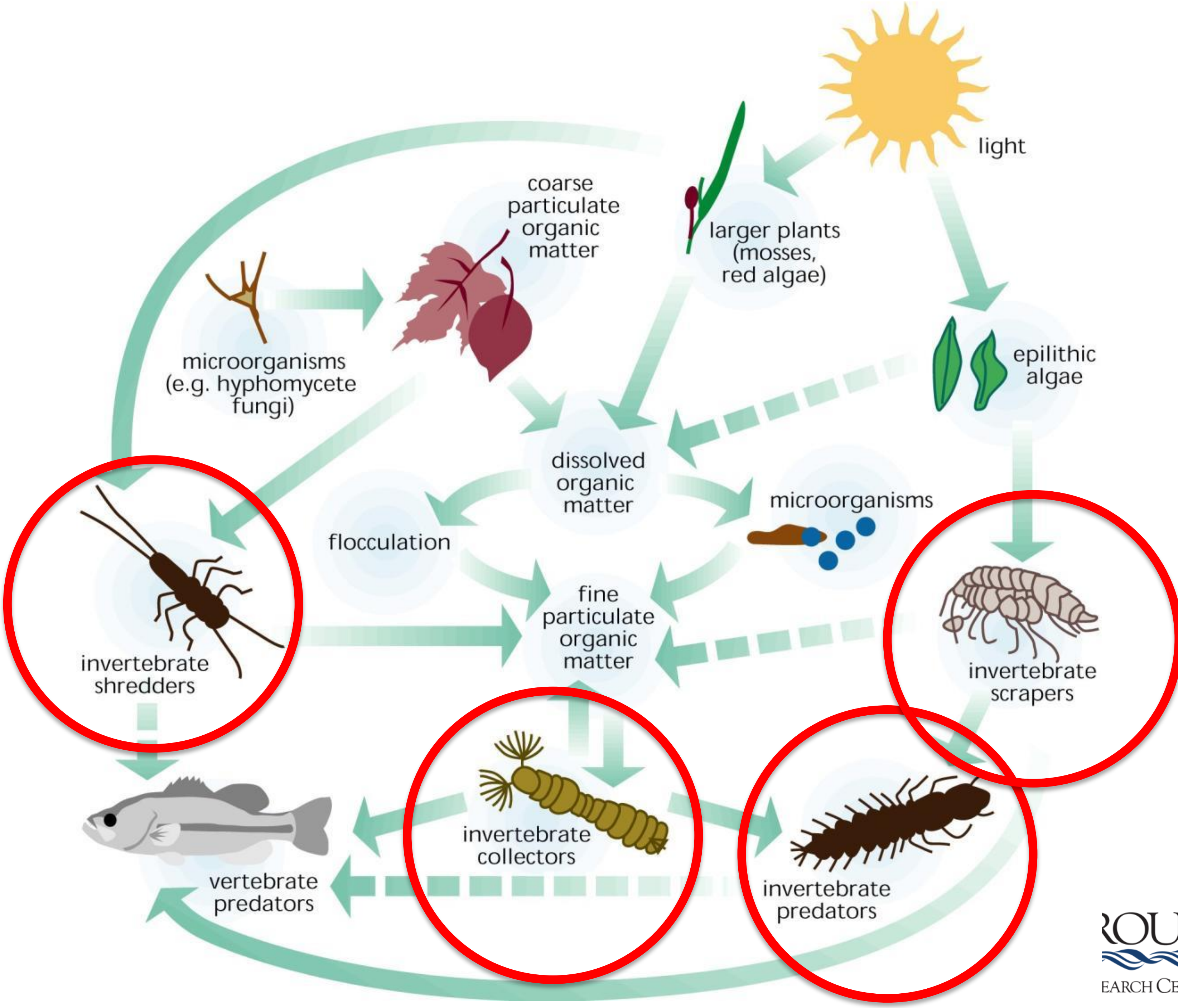


Figure: The processing or 'conditioning' sequence for a deciduous tree leaf in a temperate stream.



ROUD
EARCH CENTER

Functional Feeding Groups

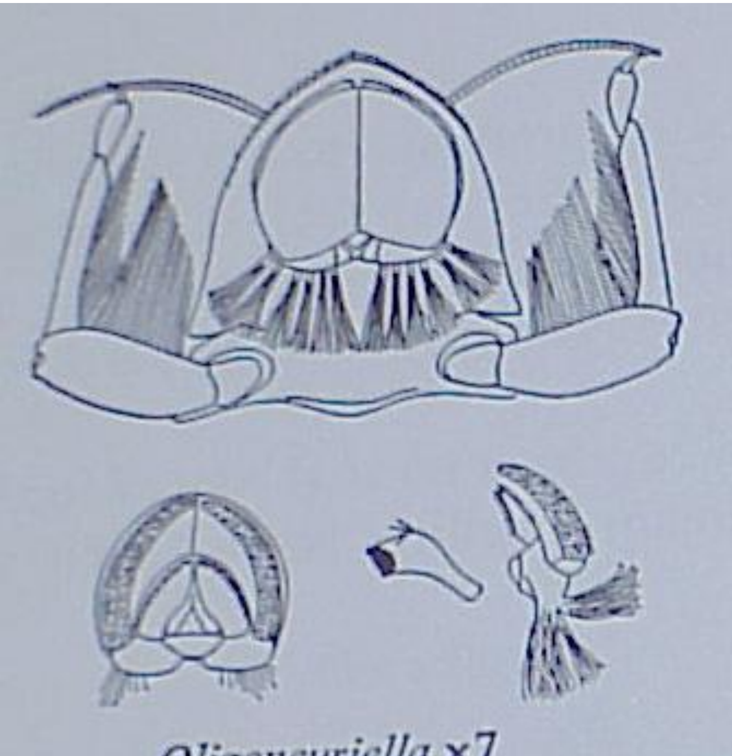
Feeding mechanisms – size of food & location

- **Shredder** – live or dead plants – feed on Coarse Particulate Organic Matter (CPOM > 1 mm)
- **Collector-filter** – suspension feeder - feed on Fine Particulate Organic Matter (FPOM < 1 mm)
- **Collection gather** – deposit feeder - feed on Fine Particulate Organic Matter (FPOM)
- **Scraper** – grazer on biofilm- algae, bacteria, fungi, FPOM
- **Predator**

STROUD™ WATER RESEARCH CENTER

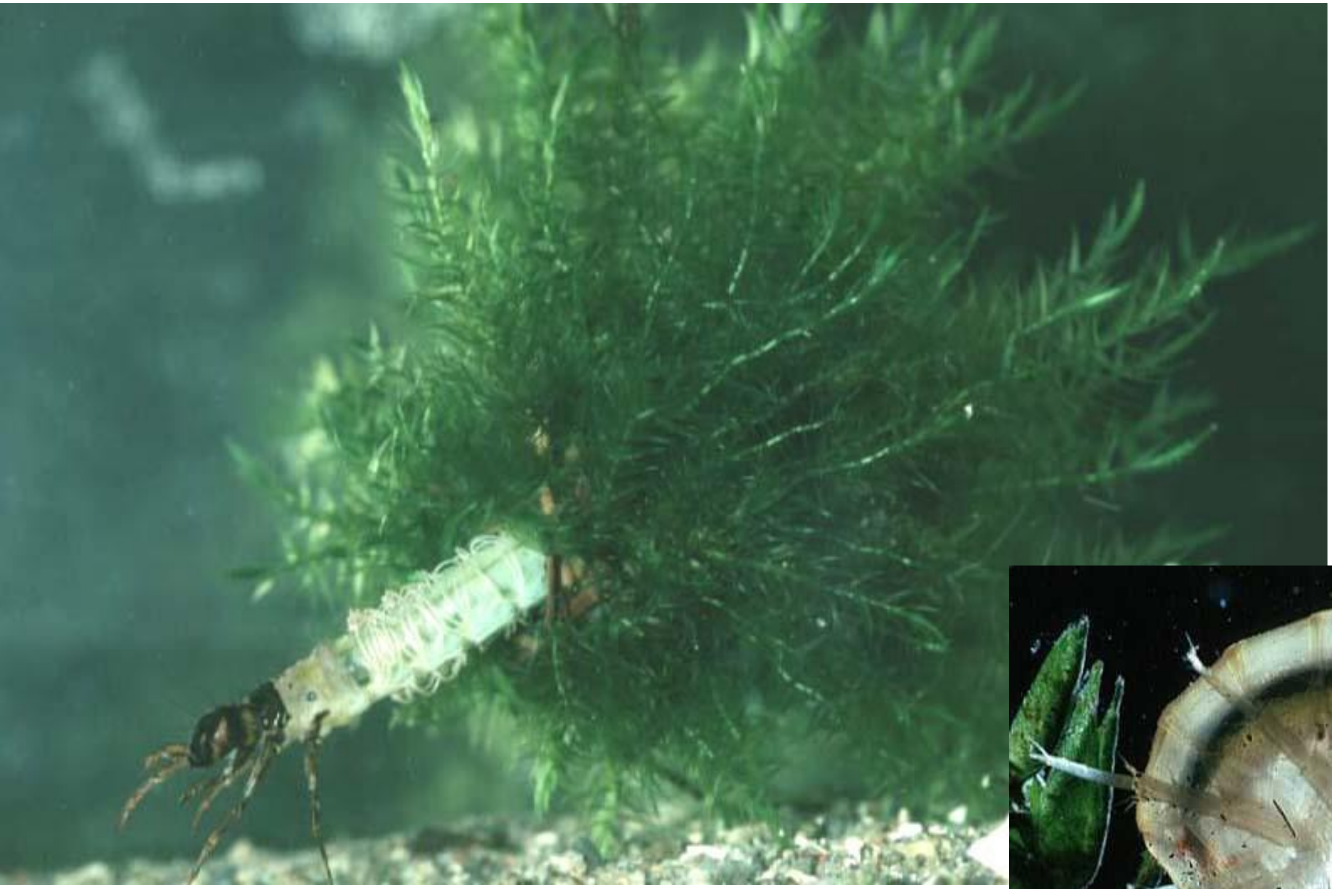
Shredders

Collector-Filterers



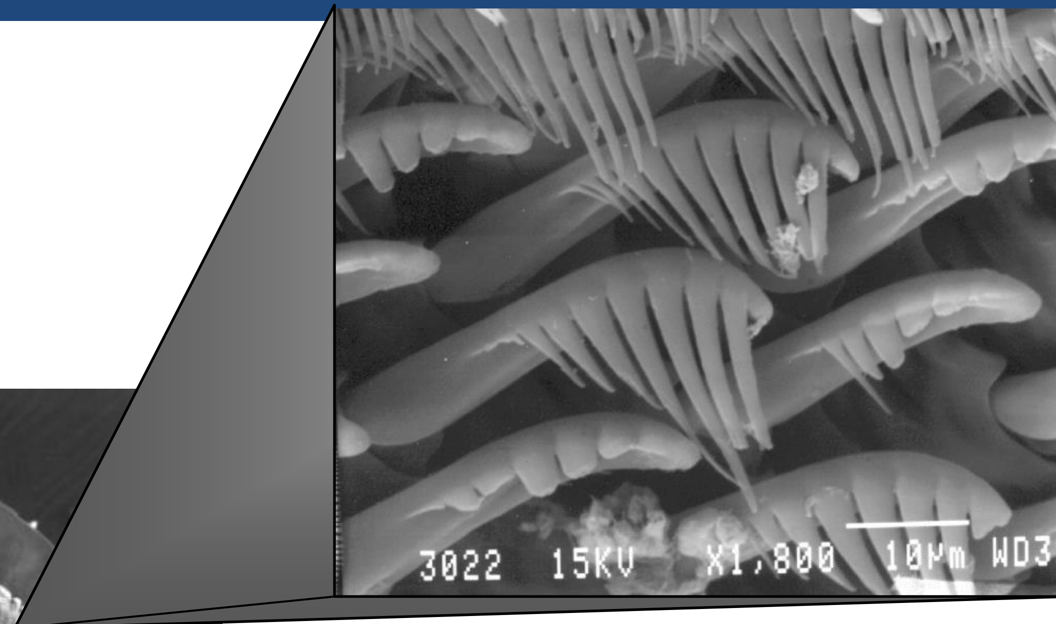
STROUD
WATER RESEARCH CENTER

Collector-Gatherer

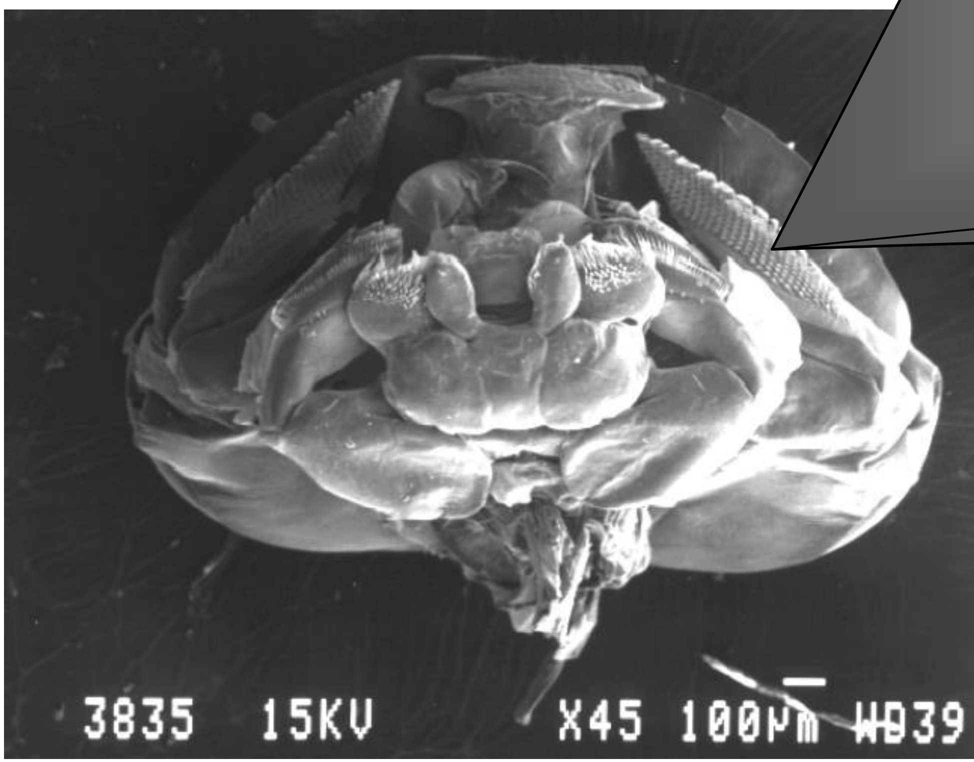


Scrapers

Scraper Feeding



Rhithrogenia pellucida head capsule



Rhithrogenia pellucida maxillary palps

Predators

Questions that I will address today:

1) Why do I study aquatic macroinvertebrates?

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

5) What determines species richness and diversity – aquatic or terrestrial?

STROUD WATER RESEARCH CENTER

Life Histories

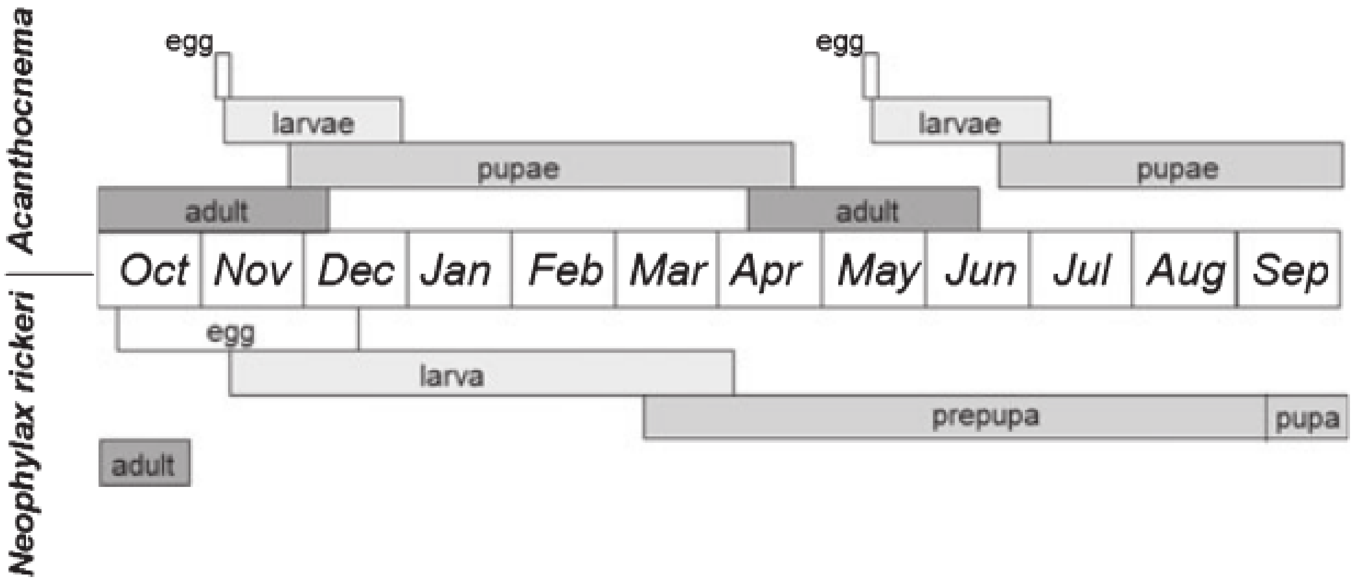
Are invertebrate populations dynamic?

Univoltine – 1 generation per year

Bivoltine – 2 generations per year

Semivoltine – > 1 year per generation (2-4, 7+)

Multivoltine – > 2 generations per year



Bivoltine Dipteran

Univoltine caddisfly

Life history of a dipteran predator (Scathophagidae: *Acanthocnema*) of insect egg masses in a northern California stream. Freshwater Biology 53(12):2426 - 2437 · July 2008

Univoltine caddisflies

Fast seasonal
Slow seasonal
Non-seasonal

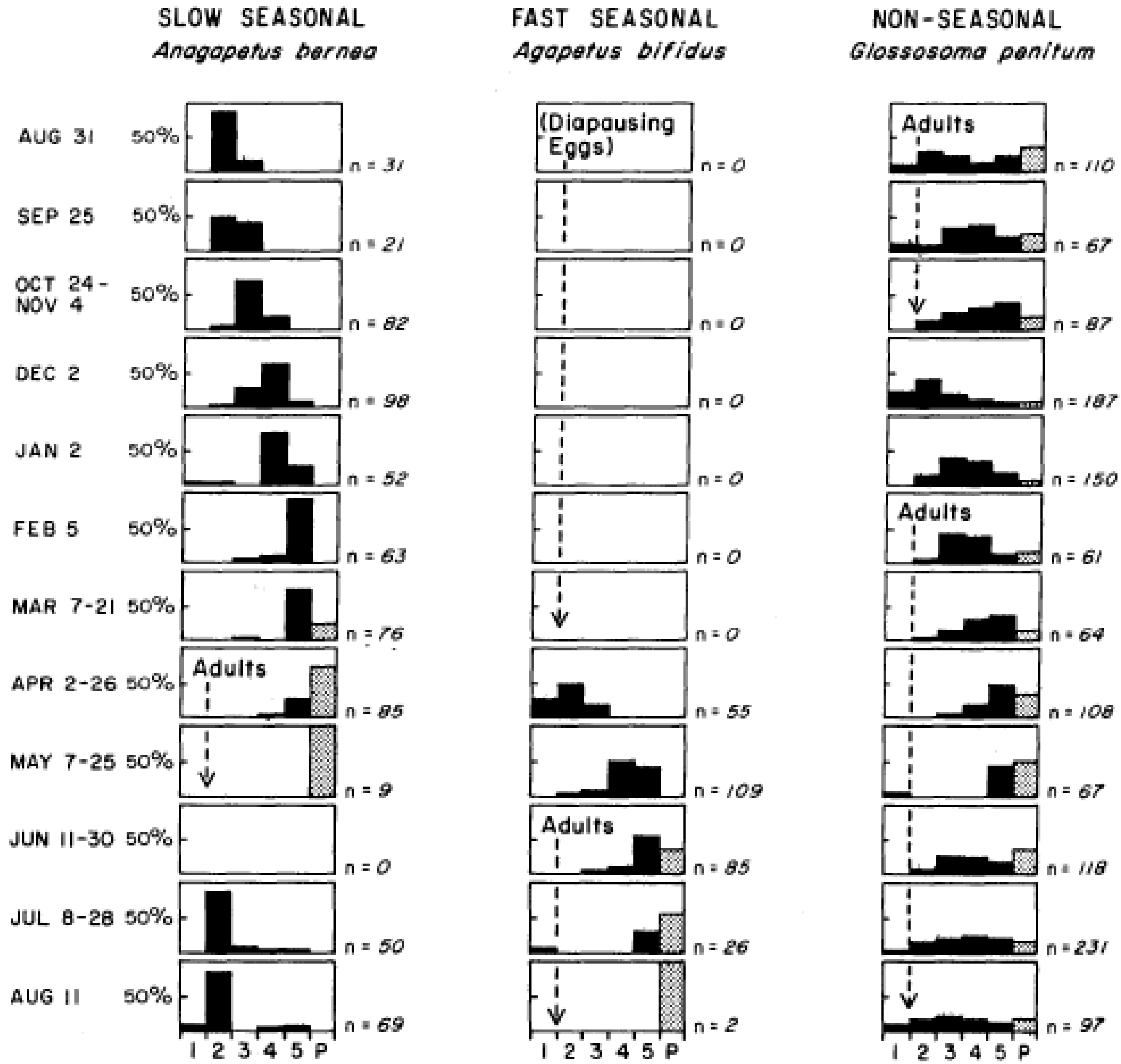
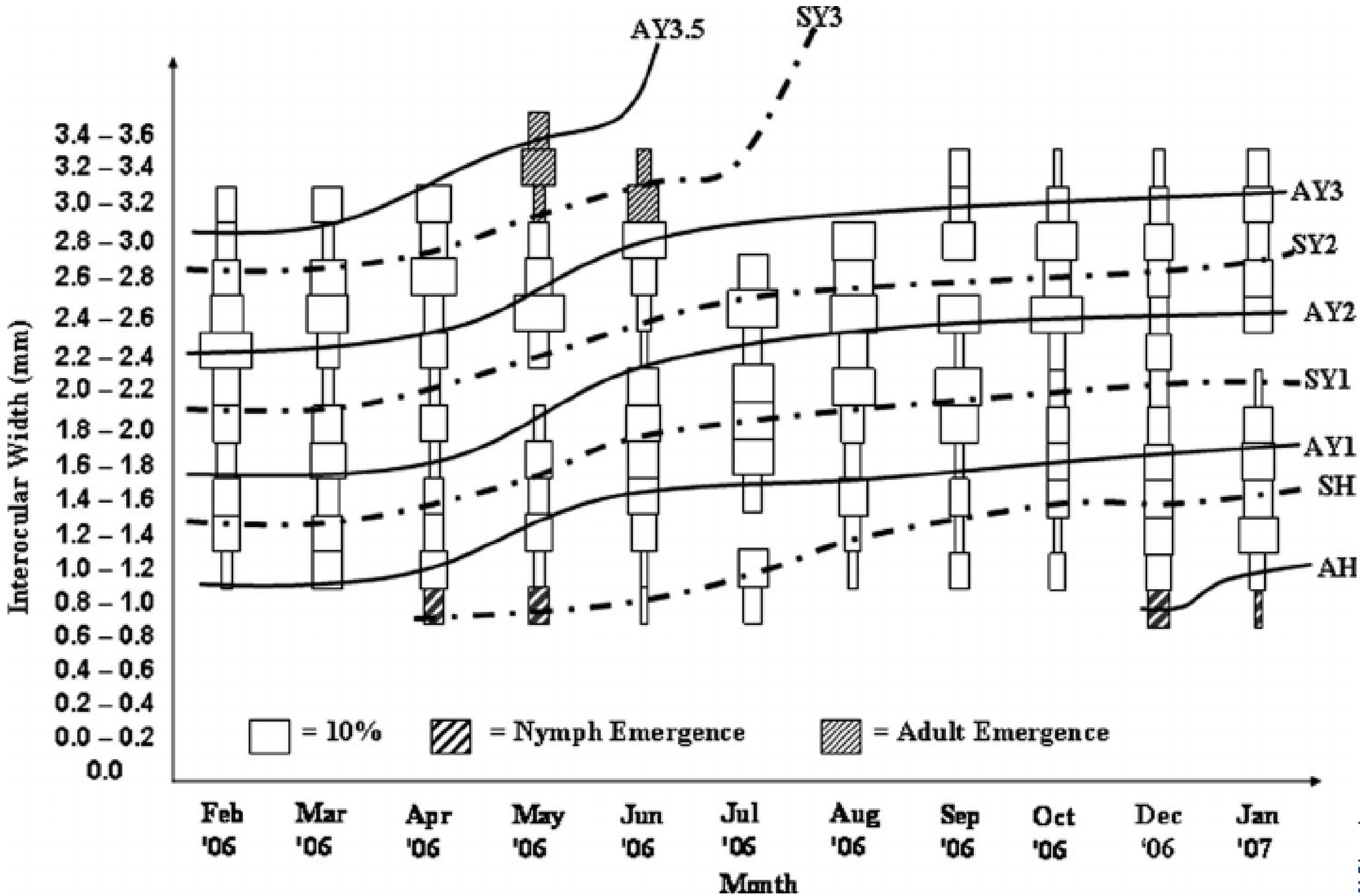


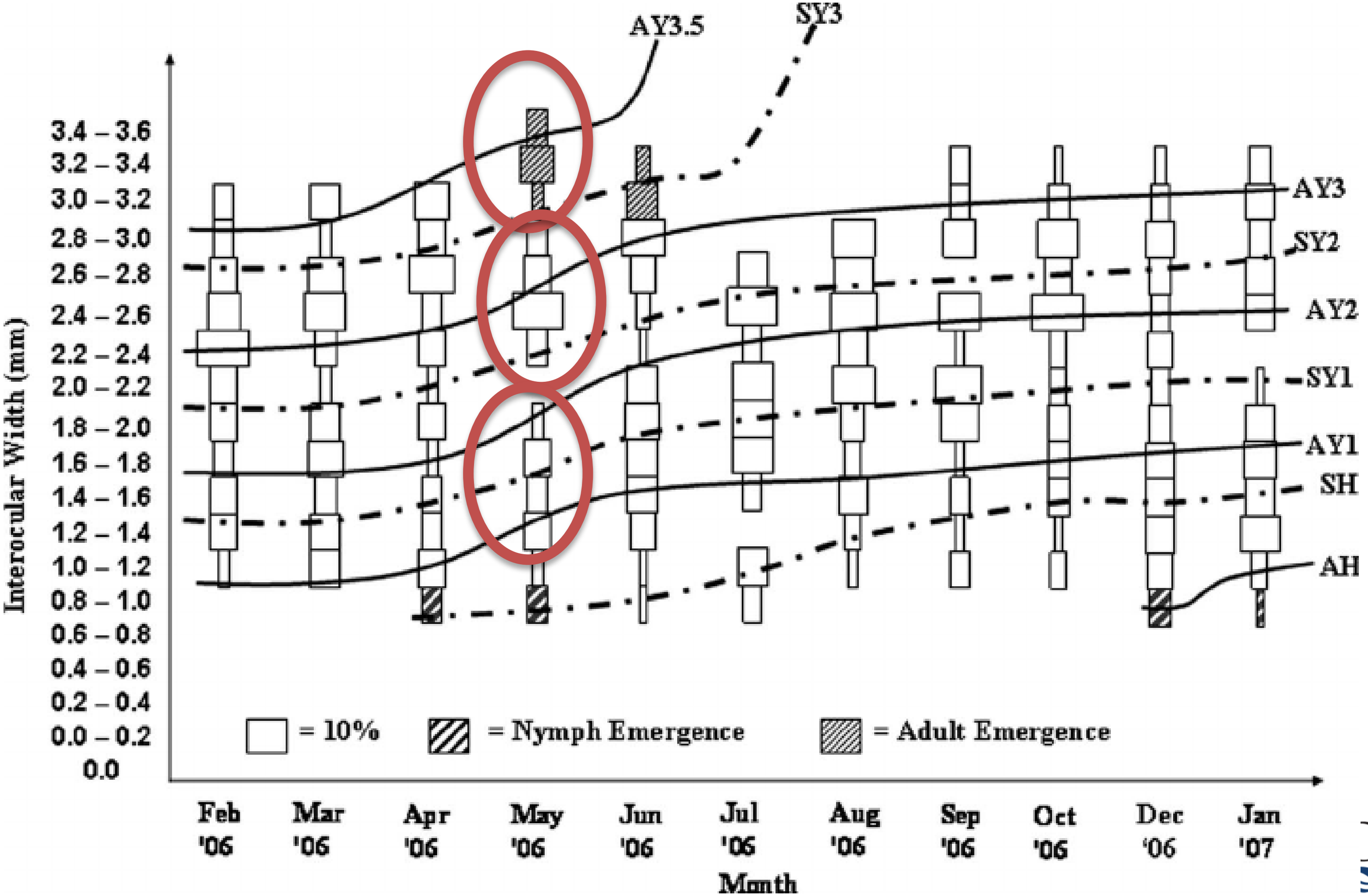
Figure 5.2. Age distribution of three glossosomatid caddisflies, illustrating life cycles. Field data are expressed as percentage composition per month for each instar. There are five larval instars; *P* = prepupa + pupa; *n* = number per sample. Flight period of adults is also indicated. (Data from Anderson and Bourne [1974].)

Semivoltine stonefly
Perlidae *Perla bipunctata*
3-yr life cycle



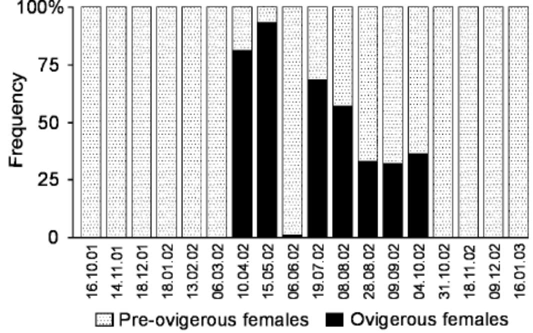
The life history of *Perla bipunctata* Pictet, 1833 (Plecoptera: Perlidae) in the upper River Liffey, Ireland. Aquatic Insects 31(4):261-270 · December 2009

Semivoltine stonefly
Perlidae *Perla bipunctata*
3-yr life cycle

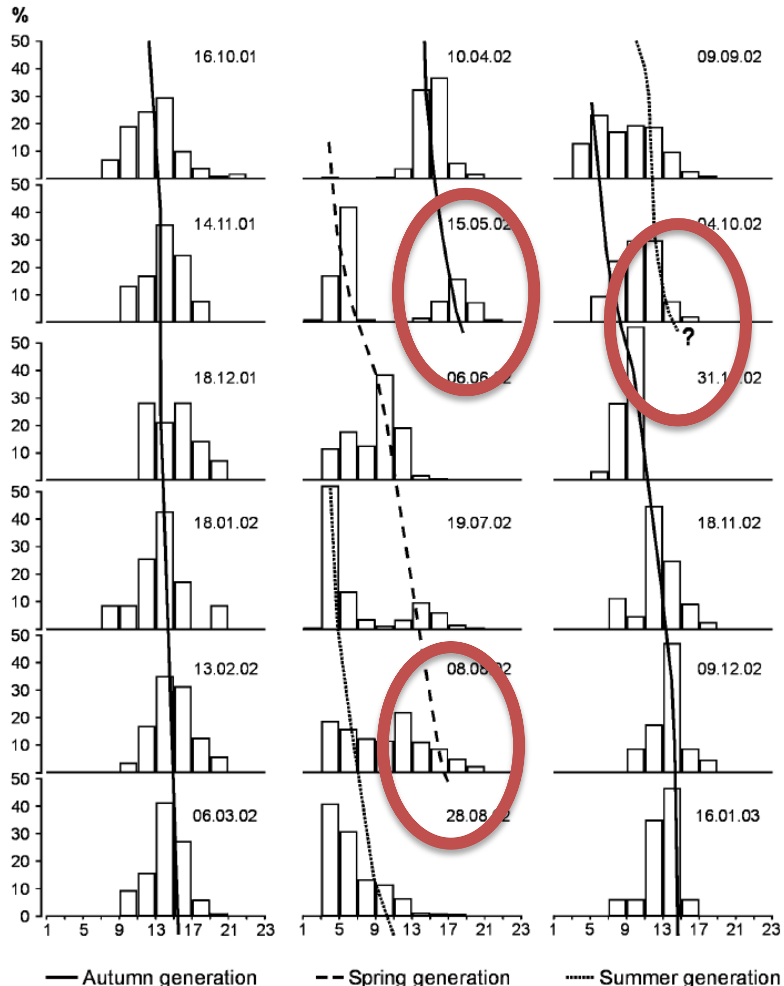


The life history of *Perla bipunctata* Pictet, 1833 (Plecoptera: Perlidae) in the upper River Liffey, Ireland. Aquatic Insects 31(4):261-270 · December 2009

3 generations per year



Slow winter
Fast summer
Fast autumn



Emergence in
Apr-May
Jul-Aug
Oct

Fly Fisherman's Hatch Chart

West Virginia North Fork River - Hatch Chart

Mayfly Name	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Remarks
Little Blue Winged Olive									s18, early PM
Quill Gordon									s12, 14 early/mid PM
Little Blue Quill									s16, 18 late AM/early PM
Henderickson									s12,14 early/mid PM
Gray Fox									s12,14 early/mid PM
March Brown									a10,12 sporadic PM
Green Drake									s8,10 early/late PM
Little Maryatt									s14 late AM/late PM
Sulfur Dun									s12 late AM/late PM
Little Sulfur Dun									s18 mid/late PM
Blue Winged Olive									s12,14 AM sporadic
Light Blue Winged Olive									s16 AM sporadic
Tiny White Winged Black									s22,28 early AM/PM
Dun Var Mahogany Dun									s10,12 mid/late PM
Light Cahill									s12,14 PM sporadic
Cream Varient									s10 dusk late PM
Pale Evening Dun									s14,16 evening
Yellow May									a10,12 mid/latePM
Dark Blue Quill									s16,18 mid/late PM
Week	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4	

*** Note: Hatch Chart based upon data from "Charlie Charmers

*** Start and End Dates may vary depending on weather

S - Hook Size & Time of Day

Fly Fisherman's Hatch Chart

West Virginia North Fork River - Hatch Chart																																	
Mayfly Name	**Mar**				**Apr**				**May**				**Jun**				**Jul**				**Aug**				**Sept**				**Oct**				**Remarks**
Little Blue Winged Olive			■	■	■	■	■																										s18, early PM
Quill Gordon						■	■	■	■	■																							s12, 14 early/mid PM
Little Blue Quill						■	■	■	■																								s16, 18 late AM/early PM
Henderickson							■	■	■	■																							s12,14 early/mid PM
Gray Fox											■	■	■	■	■																		s12,14 early/mid PM
March Brown											■	■	■	■																			a10,12 sporadic PM
Green Drake												■	■	■	■																		s8,10 early/late PM
Little Maryatt											■	■	■																				s14 late AM/late PM
Sulfur Dun											■	■	■																				s12 late AM/late PM
Little Sulfur Dun											■	■	■	■	■																		s18 mid/late PM
Blue Winged Olive													■	■	■	■	■	■															s12,14 AM sporadic
Light Blue Winged Olive													■	■	■	■	■	■															s16 AM sporadic
Tiny White Winged Black													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			s22,28 early AM/PM
Dun Var Mahogany Dun														■	■	■	■	■	■	■	■	■	■	■									s10,12 mid/late PM
Light Cahill														■	■	■	■	■	■														s12,14 PM sporadic
Cream Varient															■	■	■	■	■														s10 dusk late PM
Pale Evening Dun															■	■	■	■	■														s14,16 evening
Yellow May														■	■	■	■	■															a10,12 mid/latePM
Dark Blue Quill															■	■	■	■	■	■													s16,18 mid/late PM
Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
*** Note: Hatch Chart based upon data from "Charlie Charmers																																	S - Hook Size &
*** Start and End Dates may vary depending on weather																																	Time of Day

Upper Delaware River Hatch Chart

Scientific Name	Common Name	Size	March	April	May	June	July	August	September	October	November
Baetis vagans	Blue Winged Olive	16/18									
Paraleptophlebia adoptiva	Blue Quill, Mahogany Dun	16/18									
Epeorus pleuralis	Quill Gordon	14									
Ephemerella subvaria	Hendrickson	12/14									
Ephemerella "x"	Dark Hendrickson	14/16									
Ephemerella invaria	Light Cahill	14									
Ephemerella rotunda	Sulfur/Pale Evening Dun	14									
Stenonema vicarium	March Brown	10-2XL									
Stenonema fuscum	Gray Fox	12-2XL									
Ephemerella dorothea	Sulfur	16/18/20									
Pseudocloeon	Blue Winged Olive	22/24/26									
Ephemera guttulata	Green Drake	8-2XL									
Ephemera simulans	Brown Drake	10-2XL									
Epeorus vitreus	Sulfur	14									
Isonychia bicolor	Dun Variant, Slate Drake	12-2XL/12/14									
Stenonema Ithaca & canadense	Light Cahill	14/16									
Ephemerella cornuta	Light Blue Winged Olive	14									
Ephemerella attenuata	Light Blue Winged Olive	16/18/20									
Potamanthus	Golden Drake	10									
Tricorythodes	Trico	24									
Heptagenia hebe	Olive Sulphur	18/20									
Ephemerella lata	Dark Blue Winged Olive	20/22									
Ephoron leukon	White Fly	12/14									
Capniidae sp.	Tiny Black Stone	18									
Taeniopteryx fasciata	Early Black Stone	12/14									
Brachytera sp.	Early Brown Stone	12/14									
Pteronarcys dorsata	Eastern Salmon Fly	2/4-2XL									
Pene capita	Great Brown Stone	4/10-2XL									
Acroneuria	Golden Stone	8-2XL									
Isoperla sp.	Yellow Sally	14									
Dark Chimarra	Little Black Caddis	18/20									
Dark Brachycentrus	Dark Grannom Shad Fly	14/18									
Light Brachycentrus	Apple Green Caddis	16/18									
Ryacophilia sp.	Green Caddis	16									
Psilotrta sp.	Dark Blue Sedge	14									
Hydropsyche sp.	Tan Caddis Spotted Sedge	14/16									
Glossosoma sp.	Little Tan Sedge	16/18									
Limnephilis sp.	Ginger Caddis	10/12									
Neophylax sp.	Autumn Mottled Sedge	14/16									
Pycnopsyche sp.	Great Brown Autumn Sedge	10-2XL									
N/A	Flying Ants	16-22									

http://thedelawareriverclub.com/hatch-chart/

Temperature Effects on Life Cycle

Known to be important for many stream organisms

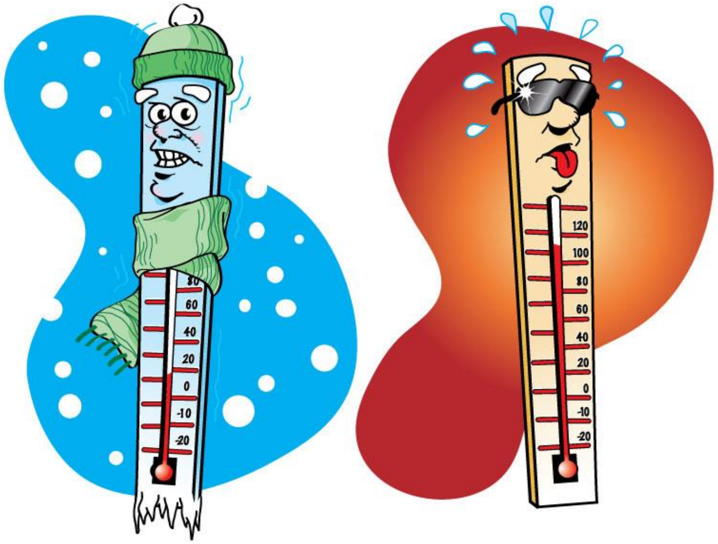
North vs South

High elevation vs Low elevation

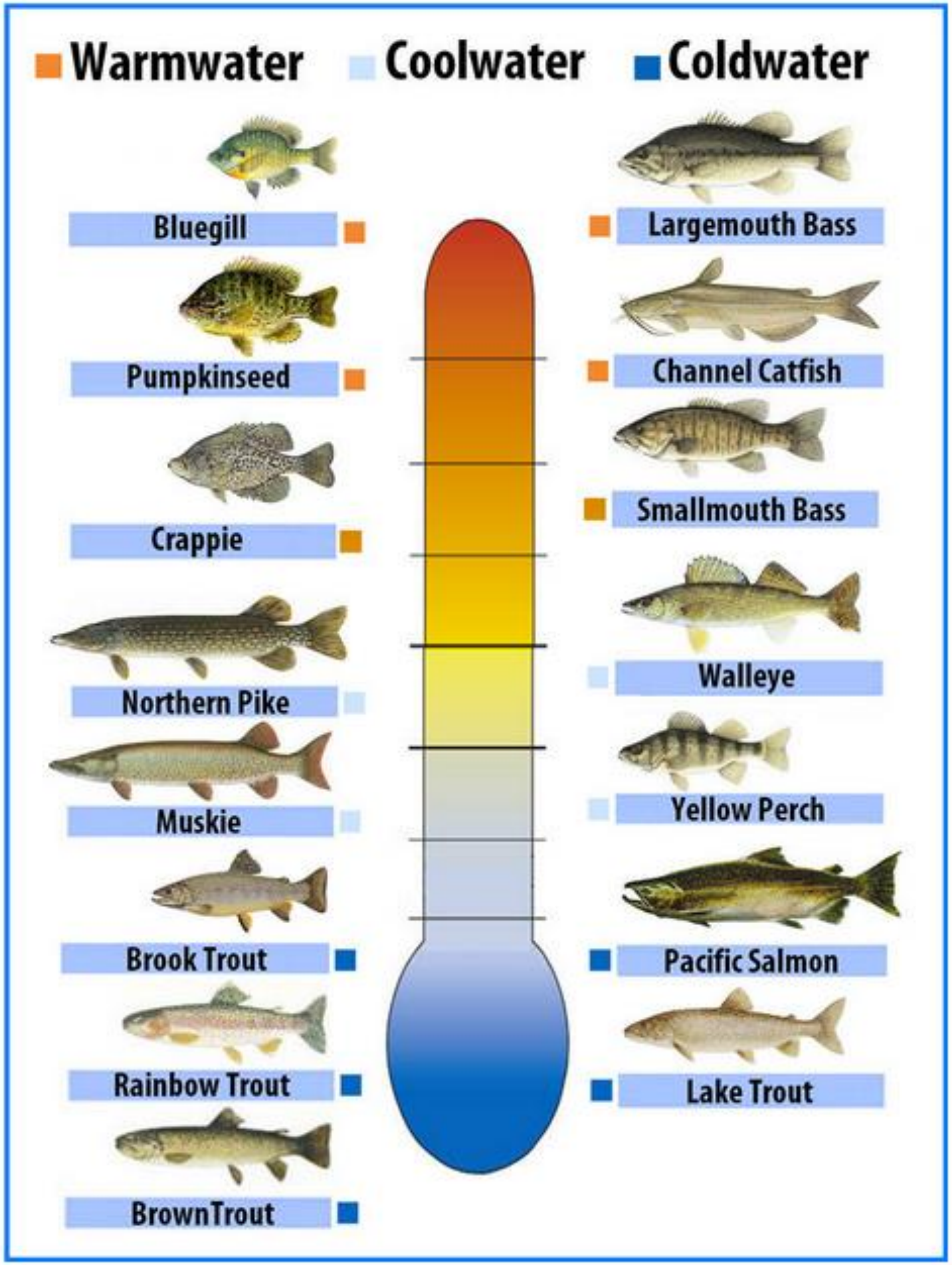
Winter vs Summer

Upstream vs Downstream

Forest vs Meadow

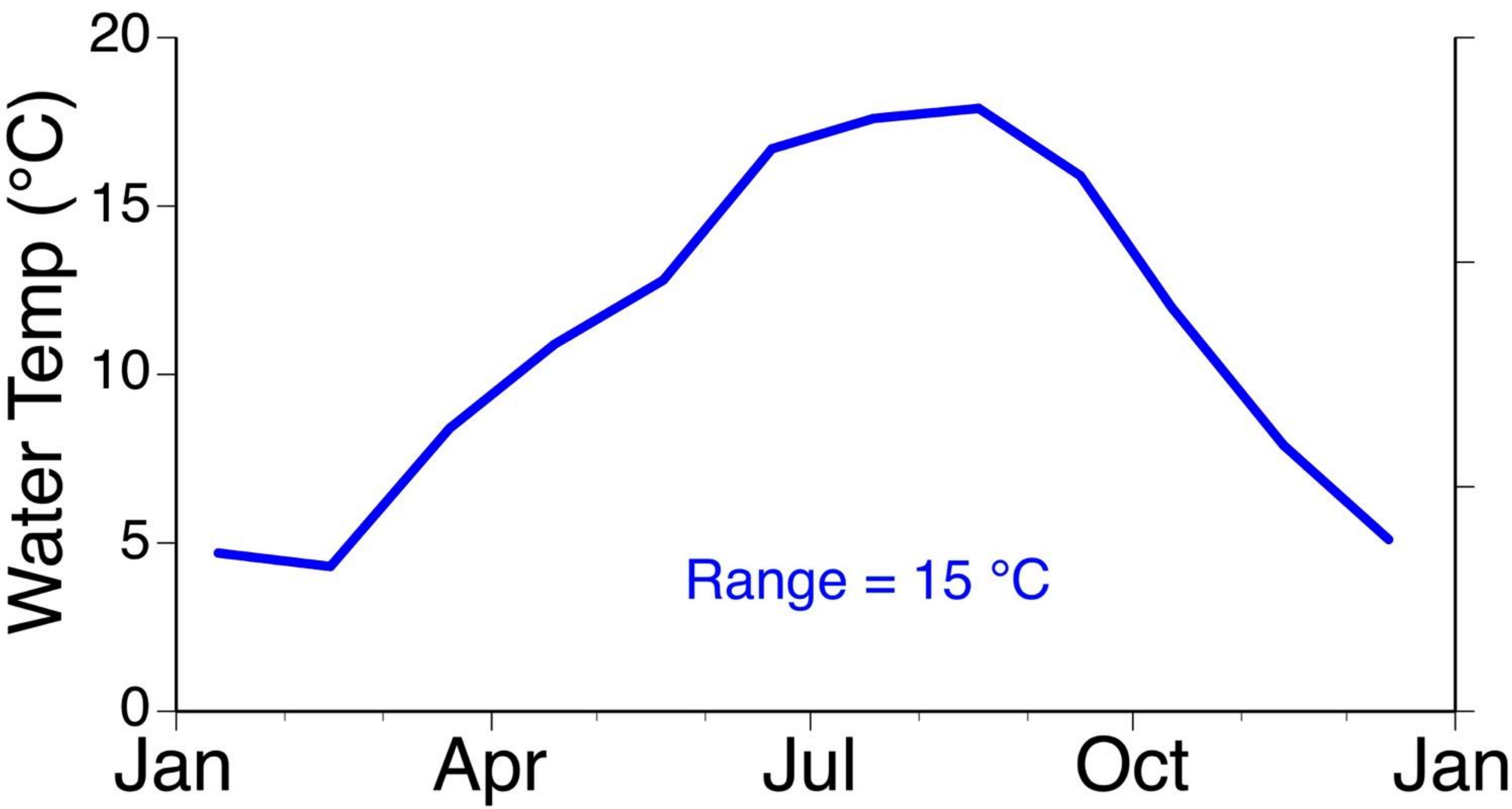


STROUD
WATER RESEARCH CENTER



STROUD
WATER RESEARCH CENTER

White Clay Creek
Mean Monthly Temp



STROUD
WATER RESEARCH CENTER

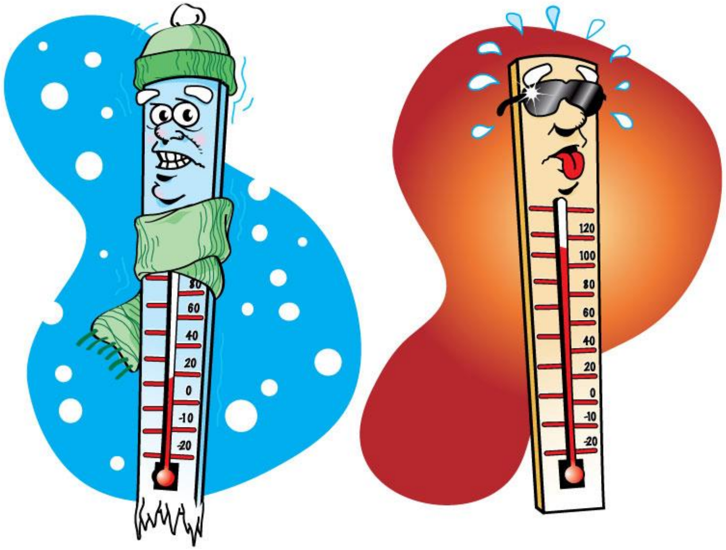
Temperature Effects on Life Cycle

Known to be important for many stream organisms

It has an effect on all macroinvertebrate **individuals** (and therefore **populations** and **communities**

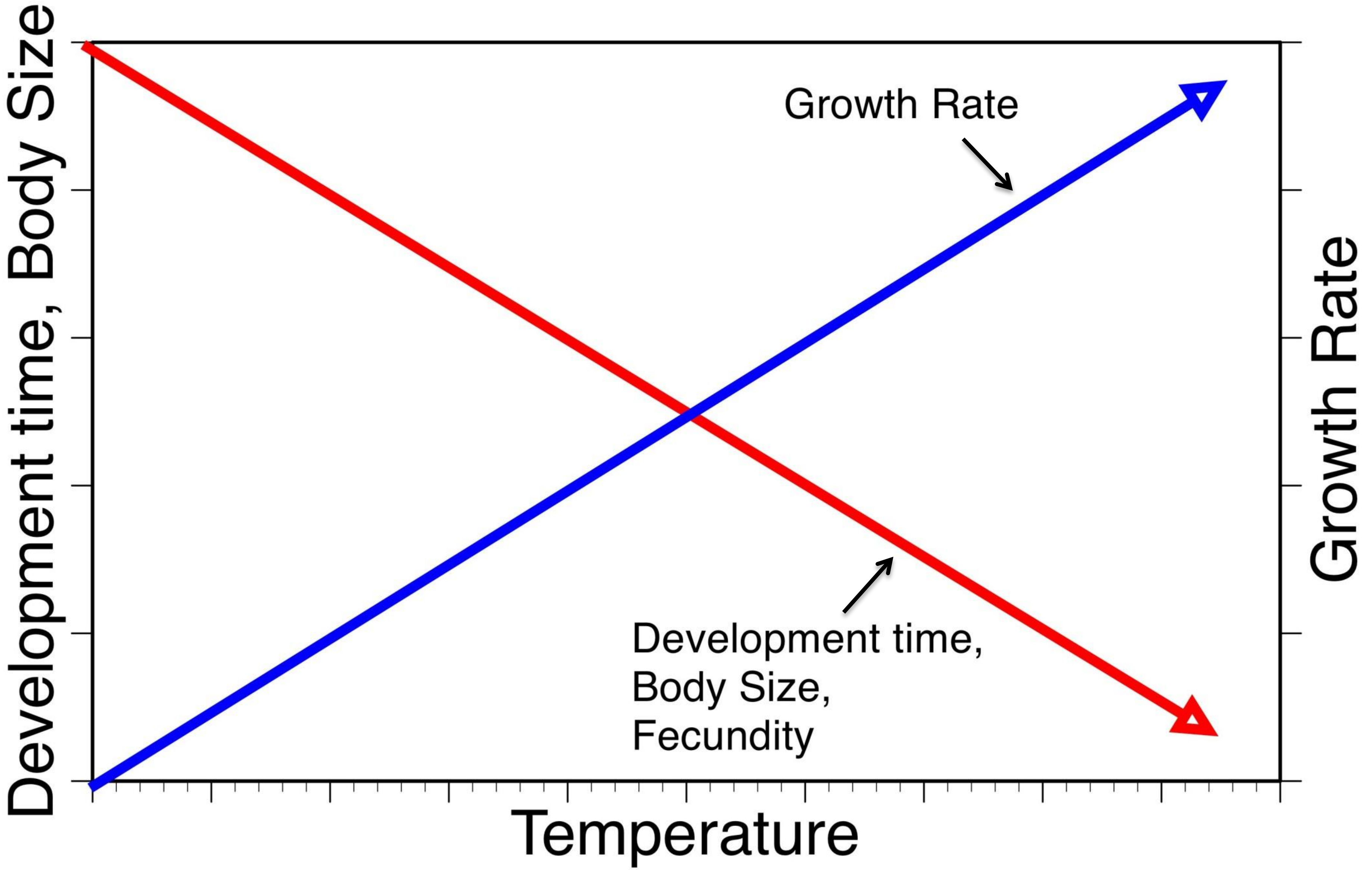
Temperature affects

- **Survival**
- **Growth rate**
- **Development time**
- **Body size/fecundity**

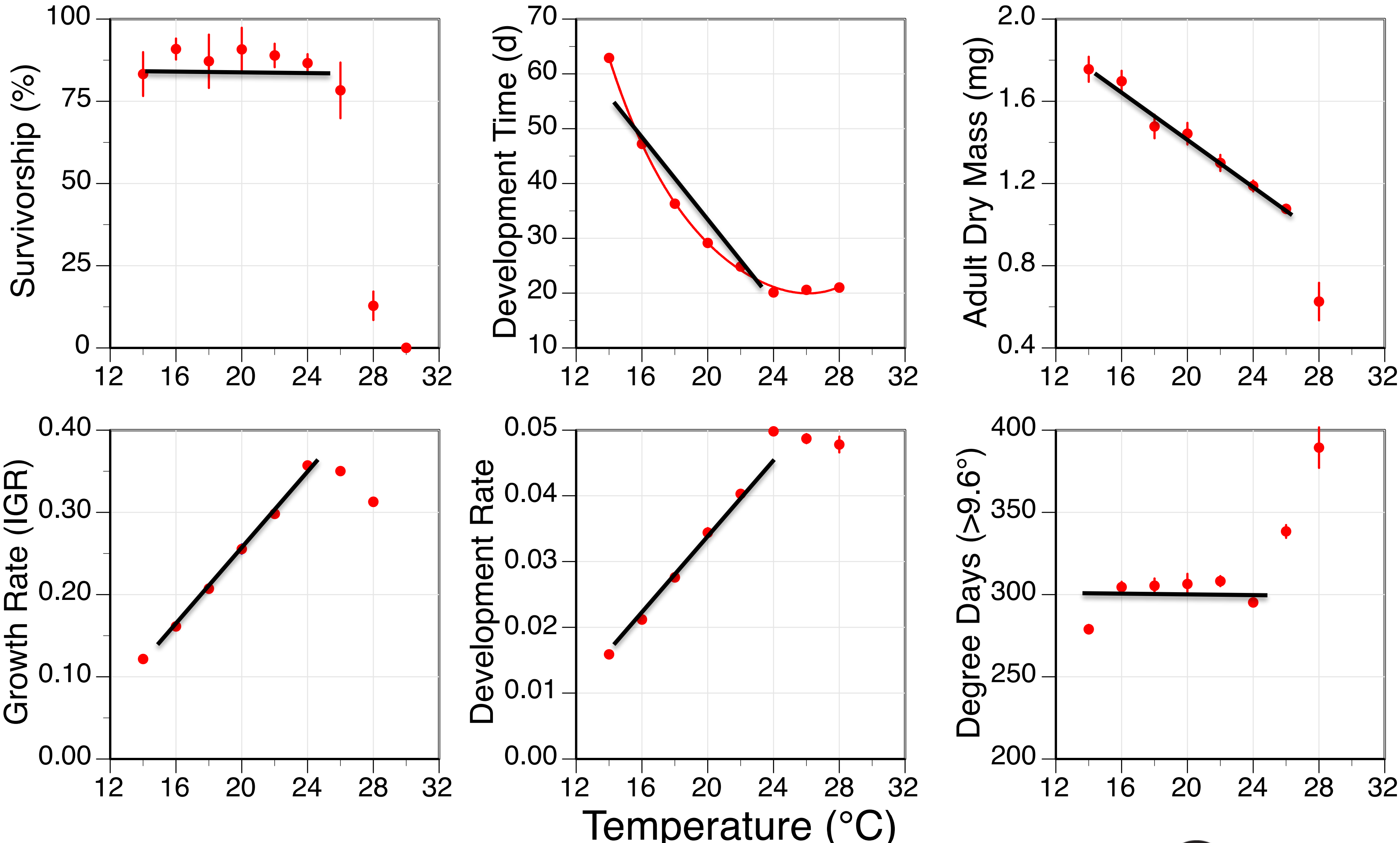


Water Research Center

Response to temperature



Neocloeon triangulifer
(Constant Temperature Experiments)



WATER RESEARCH CENTER

Factors affecting distribution and abundance

- Diversity of life in streams –
  - Breitenbach, Schlitz Germany.- Max Plank Institute (Allan 11.1, Zwick 1992)
    - **1044** species of animals over many years of collecting, **642** are insects
  - **High numbers of insects not unusual for streams**
    - Upper Three Runs in SC (about **350** species of insects)
    - White Clay Creek PA (**300** sp.)
    - Rio Tempisquito partial collections in Costa Rica **(>300 sp**.)
- In contrast, a high alpine stream in the Rockies or Alps might only have **50 species**

STROUD™ WATER RESEARCH CENTER

Questions that I will address today:

1) Why do I study aquatic macroinvertebrates?

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

5) What determines species richness and diversity – aquatic or terrestrial?

STROUD™ WATER RESEARCH CENTER

What determines species richness and diversity – aquatic or terrestrial?

Thieneman's (1954) 3 principals of species richness and diversity

- **<u>Diversity of conditions</u>**
- **<u>Deviation from normal</u>**
- **<u>Time since disturbance</u>**

STROUD WATER RESEARCH CENTER

What determines species richness and diversity – aquatic or terrestrial?

Thieneman's (1954) 3 principals of species richness and diversity

- **Diversity of conditions –** The number of species (richness) increases with increasing diversity of conditions at a locality
- **Deviation from normal** -The more conditions in a locality **deviate from normal** (i.e., normal optima of most species), the fewer species that occur. In some cases, we also see more individuals (i.e., few species, but many individuals)
- **Time since disturbance -** The longer a locality has been **in the same condition**, the richer and more stable is its biotic community

STROUD™ WATER RESEARCH CENTER

What determines species richness and diversity – aquatic or terrestrial?

Thieneman's (1954) 3 principals of species richness and diversity

- **Diversity of conditions –** The number of species (richness) increases with increasing diversity of conditions at a locality

- **Deviation from normal** -The more conditions in a locality **deviate from normal** (i.e., normal optima of most species), the fewer species that occur. In some cases, we also see more individuals (i.e., few species, but many individuals)

- **Time since disturbance -** The longer a locality has been **in the same condition**, the richer and more stable is its biotic community

STROUD WATER RESEARCH CENTER

What determines species richness and diversity – aquatic or terrestrial?

Thieneman's (1954) 3 principals of species richness and diversity

- **Diversity of conditions –** The number of species (richness) increases with increasing diversity of conditions at a locality

- **Deviation from normal** -The more conditions in a locality **deviate from normal** (i.e., normal optima of most species), the fewer species that occur. In some cases, we also see more individuals (i.e., few species, but many individuals)

- **Time since disturbance -** The longer a locality has been **in the same condition**, the richer and more stable is its biotic community

STROUD WATER RESEARCH CENTER

What determines species richness and diversity – aquatic or terrestrial?

Thieneman's (1954) 3 principals of species richness and diversity

- **<u>Diversity of conditions</u>**
- **<u>Deviation from normal</u>**
- **<u>Time since disturbance</u>**

Human activities (pollution) can affect any or all

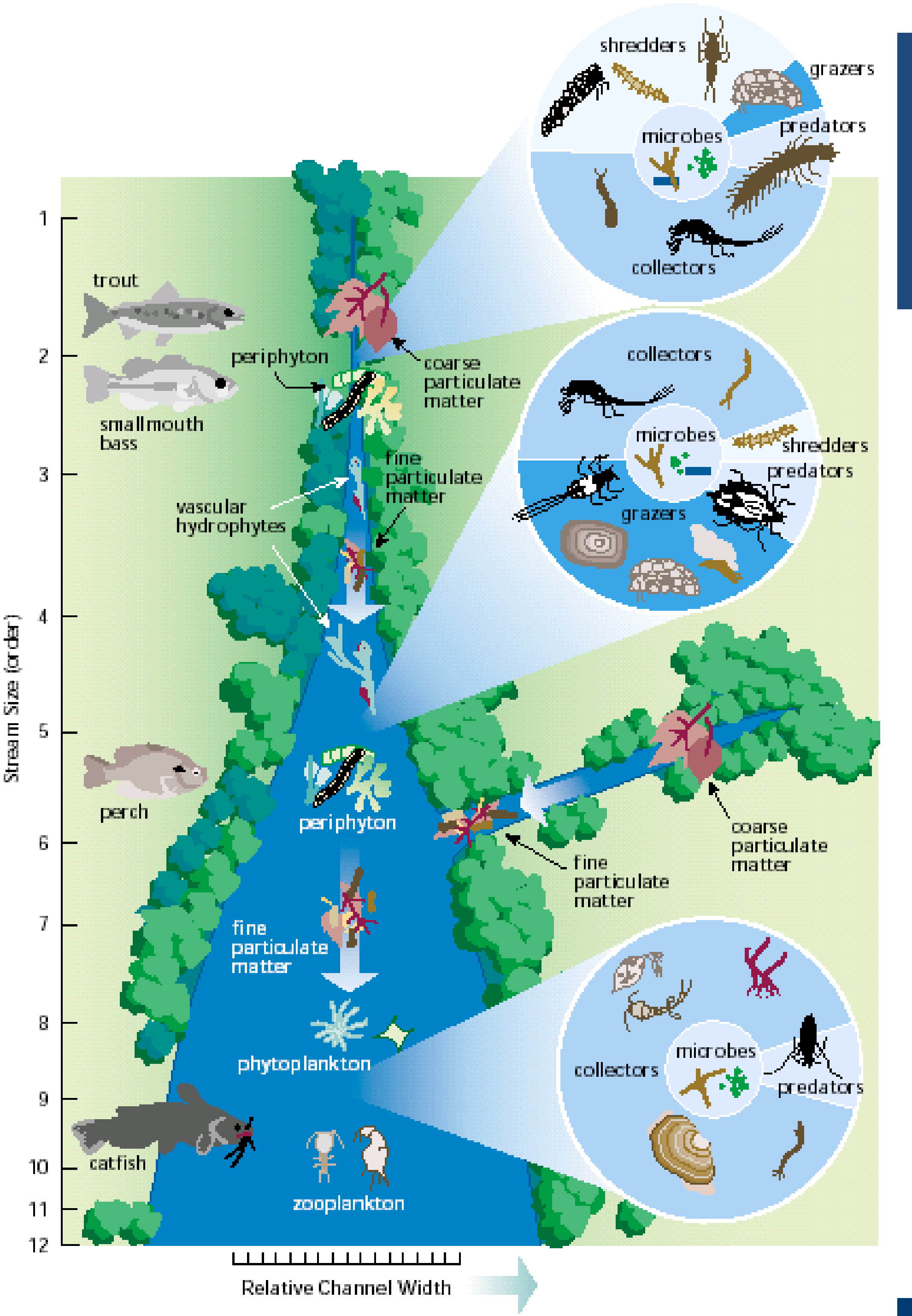
What determines species richness and diversity – aquatic or terrestrial?

- **Spatial scale** is key for total richness because it determines much of habitat diversity

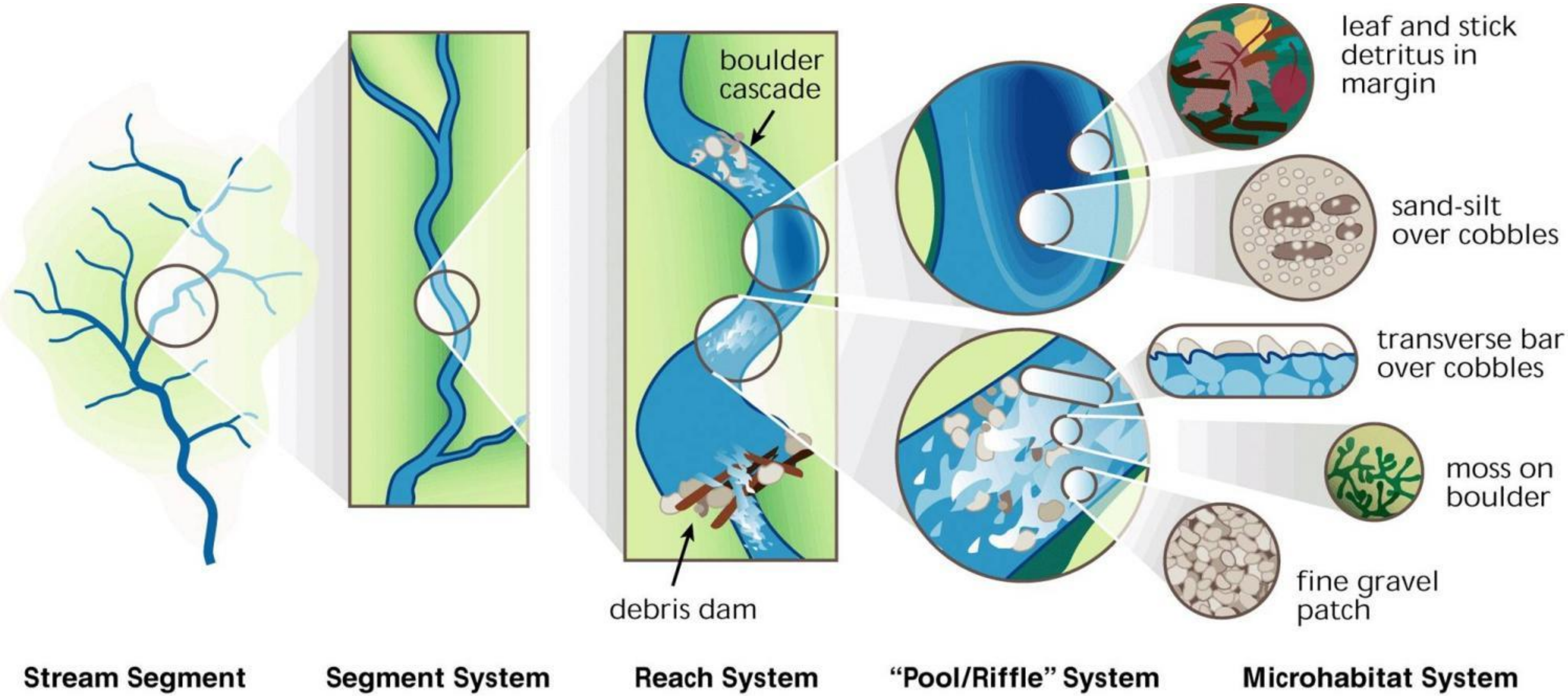
- **Individual success essential for species establishment** – dispersal, survival, growth, maturation, reproduction
  – ultimately determines **species diversity (at any spatial scale)**
    - (true for invertebrates, true also for algae, bacteria, fish, etc.)

River Continuum Concept

- •Vannote et al. (1980)
  - – Temperature
  - – Flow
  - – Substrate
  - – Food types



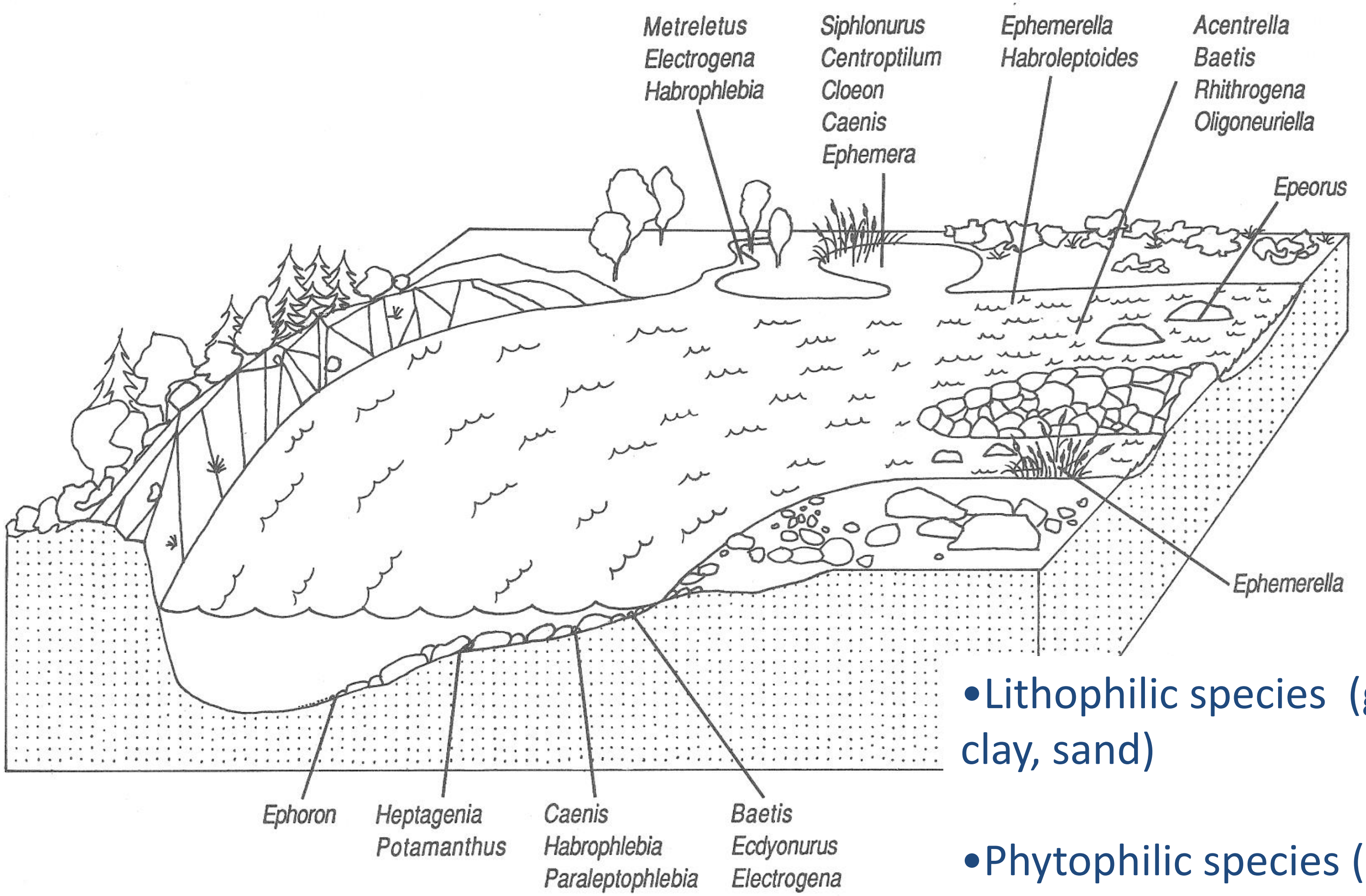
Spatial Scales of Riverine Habitat



(Frissell et al 1986)

Reach-Scale Habitat for Ephemeroptera

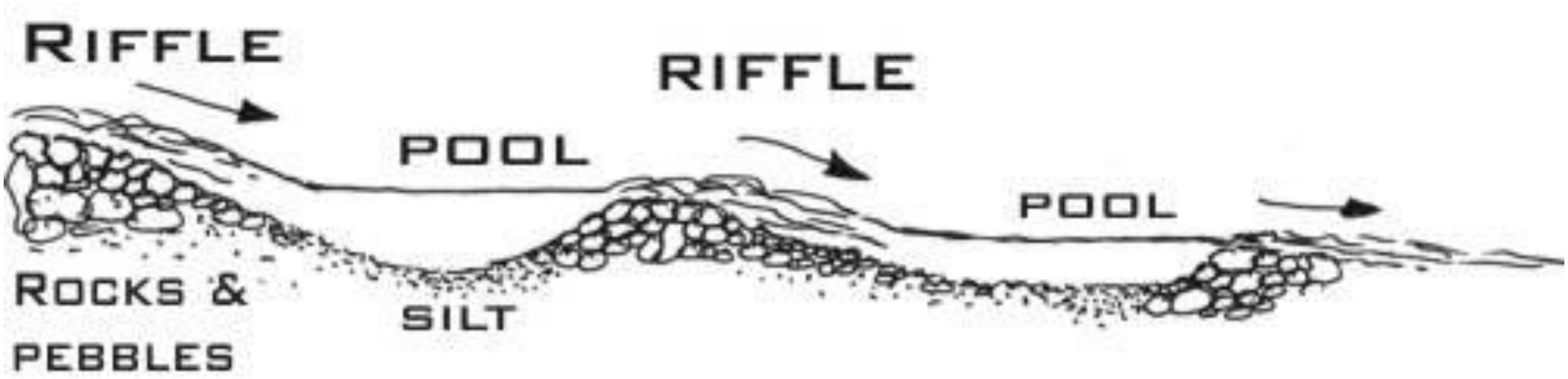
(as an example)



- Lithophilic species (gravel, clay, sand)
- Phytophilic species (plants & organic matter)

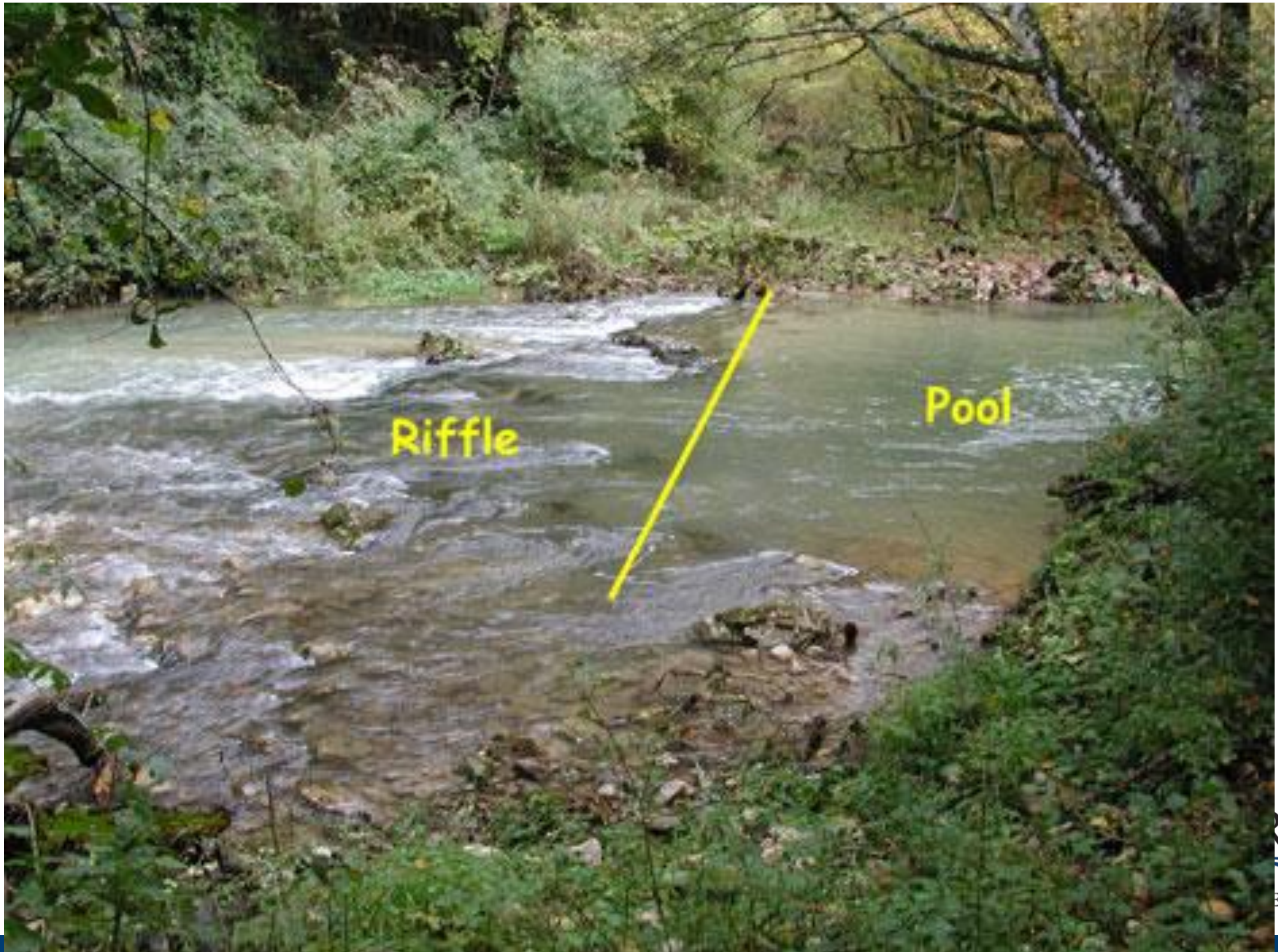
Spatial Scales of Riverine Habitat

Riffle versus Pool



Spatial Scales of Riverine Habitat

Riffle versus Pool



White Clay Creek
March 2009
Number of species in riffles versus pools

	Total Richness-Riffle	Total Richness-Pool	EPT Richness-Riffle	EPT Richness-Pool
WCC Woods	18	10	9	4

STROUD WATER RESEARCH CENTER

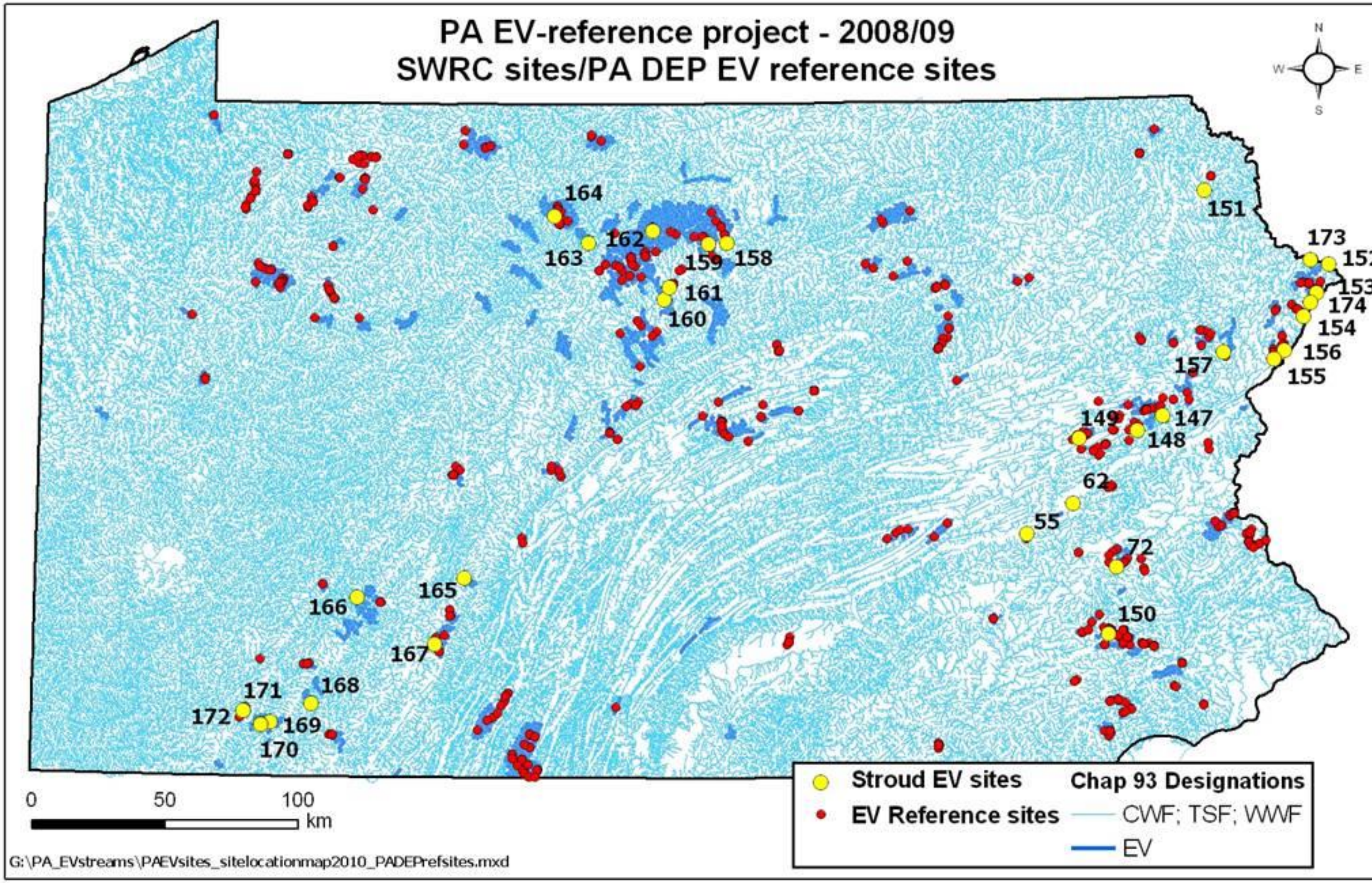
White Clay Creek
April 2008
Abundance (ind/m^2) in riffles versus pools

	Total Density-Riffle	Total Density-Pool	EPT Density-Riffle	EPT Density-Pool
WCC Woods	23,369	16,430	11,900	1,376

STROUD
WATER RESEARCH CENTER

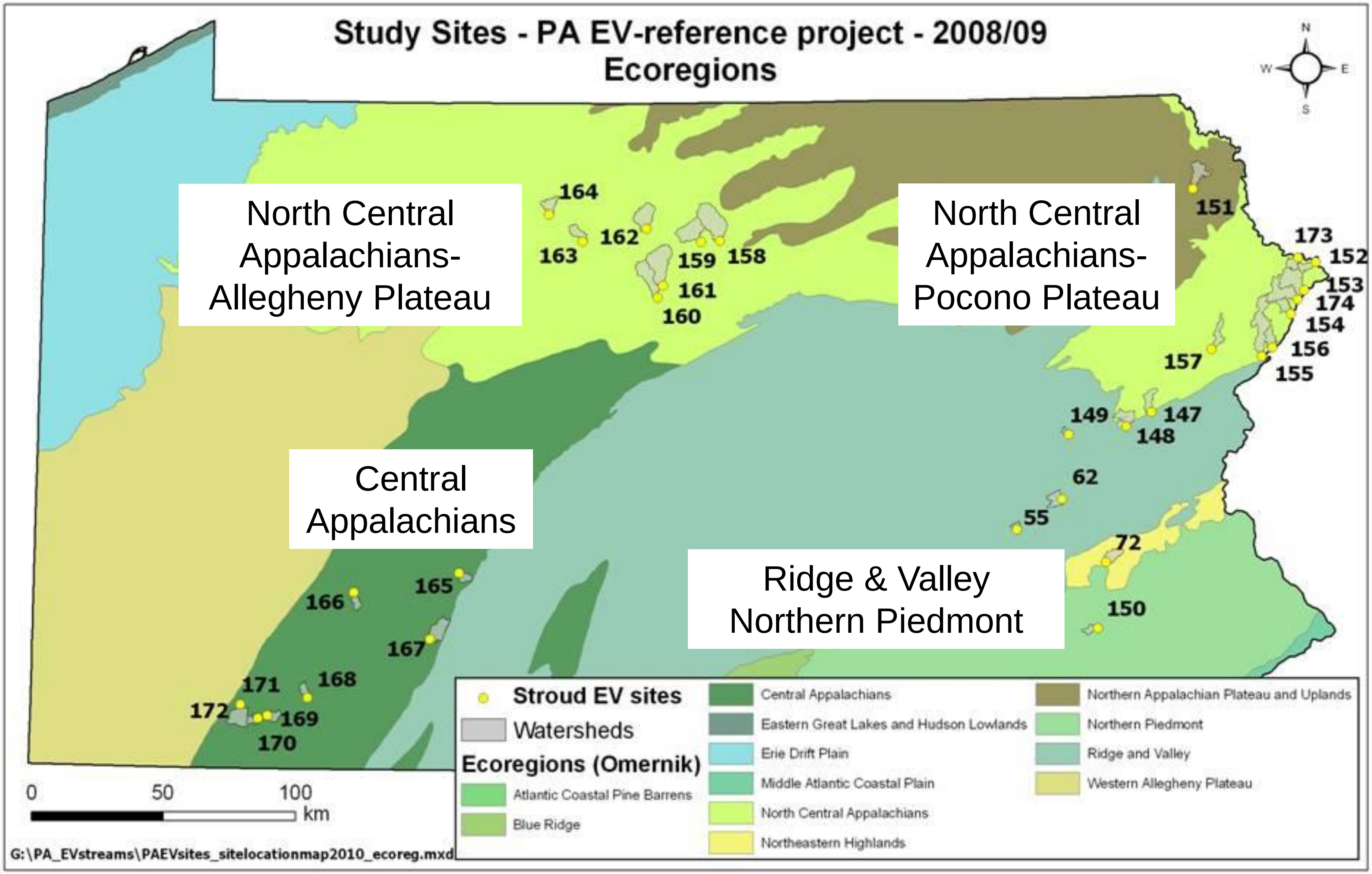
Regional Scale Differences in Streams

Geology, elevation, drainage, vegetation

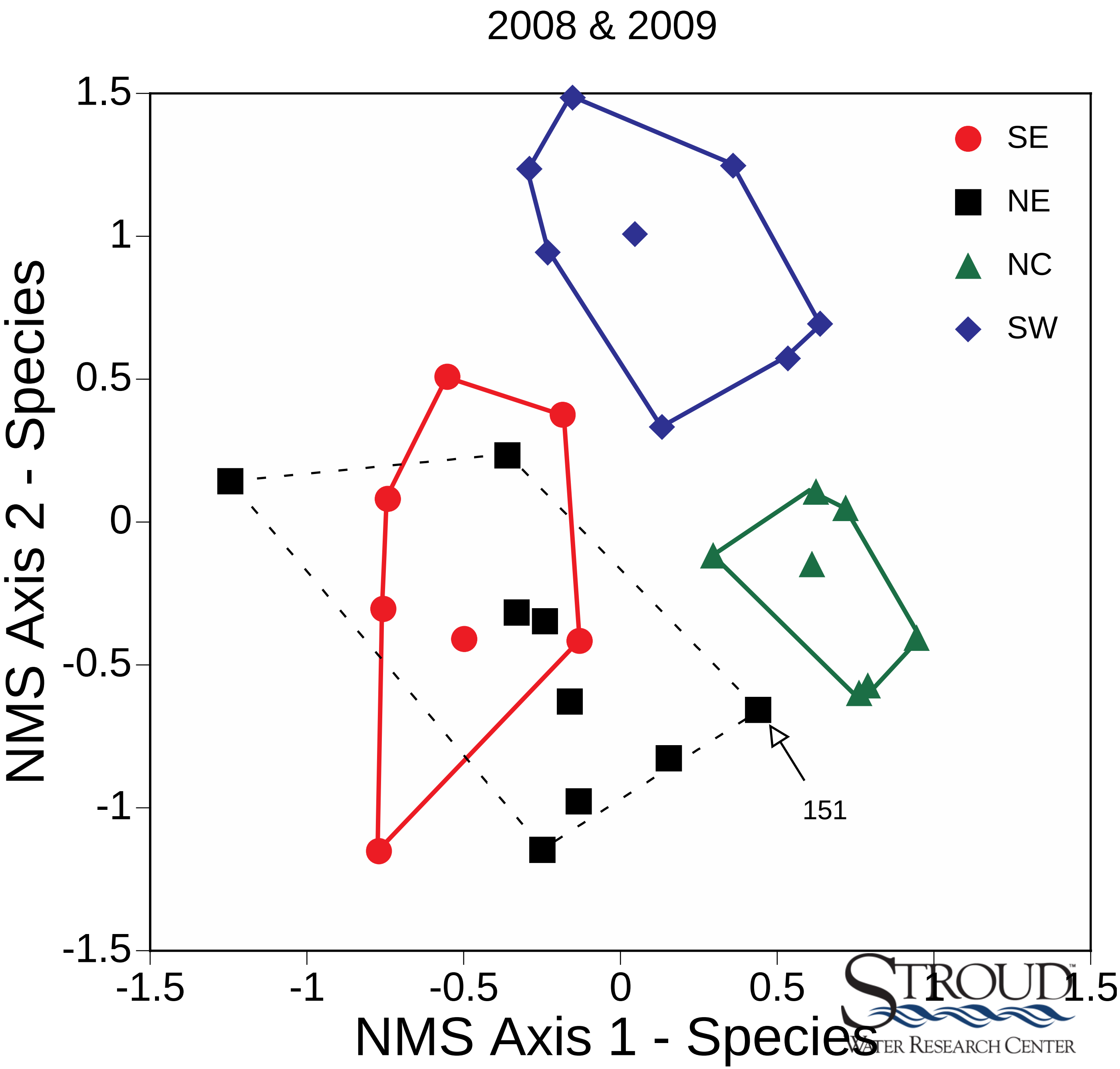


Regional Scale Differences in Streams

Geology, elevation, drainage, vegetation

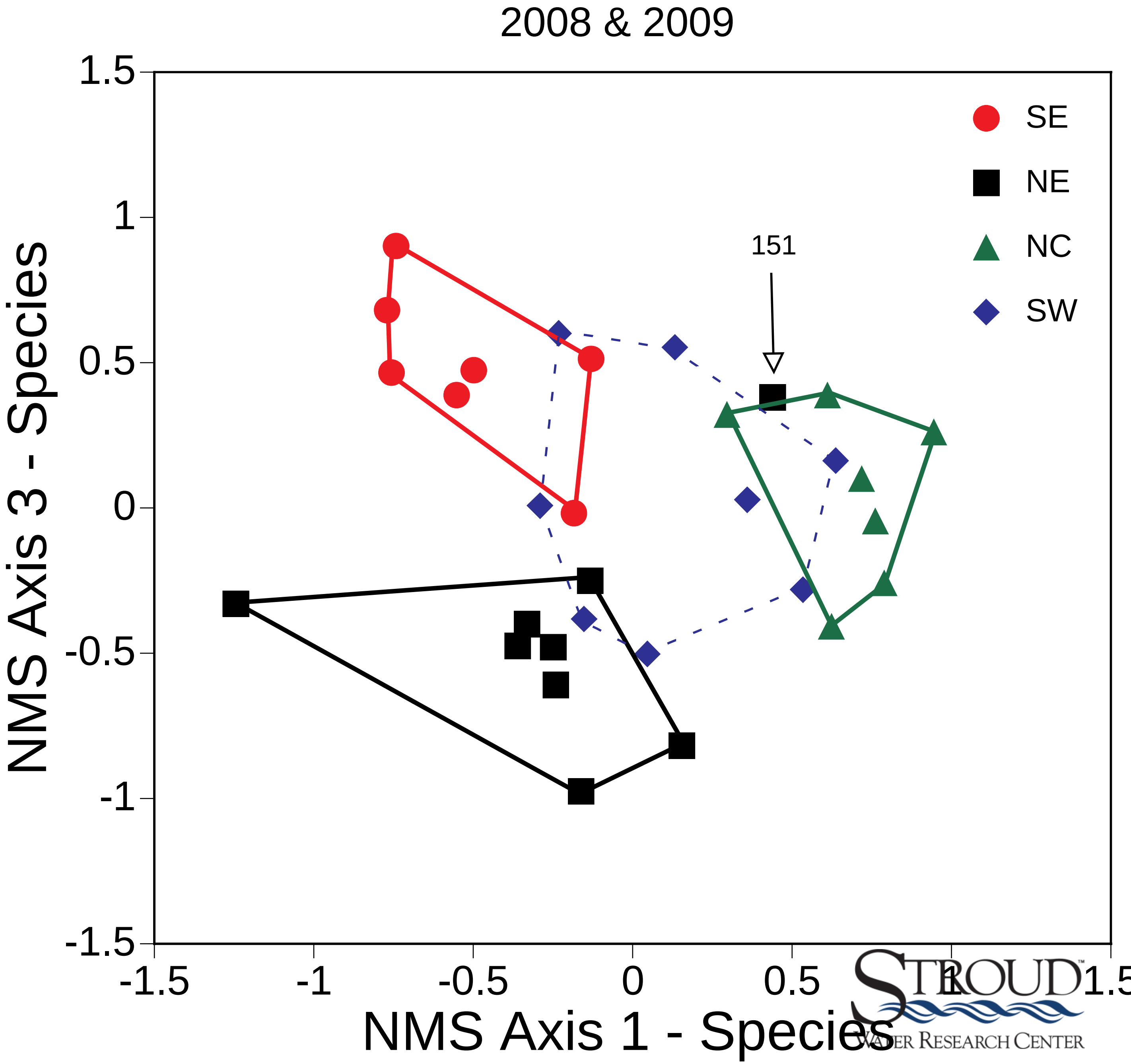


Exceptional Value Reference Streams



STROUD™ WATER RESEARCH CENTER

Exceptional Value Reference Streams



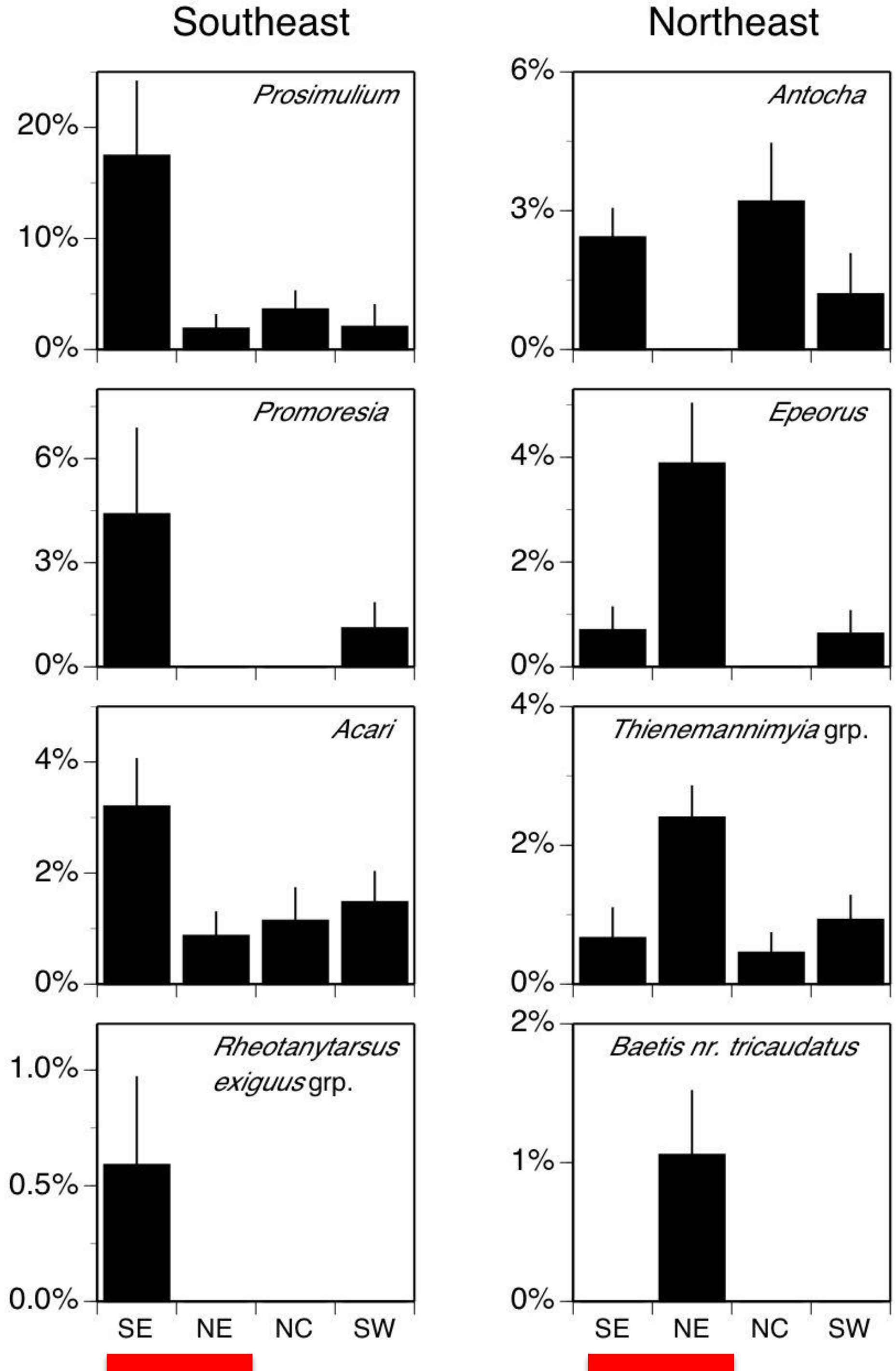
Northeast
vs
Southeast

Differences within the Delaware River Basin

North Central Appalachians-
Pocono Plateau

vs

Ridge & Valley
Northern Piedmont



River Continuum Concept

Vannote et al. (1980)

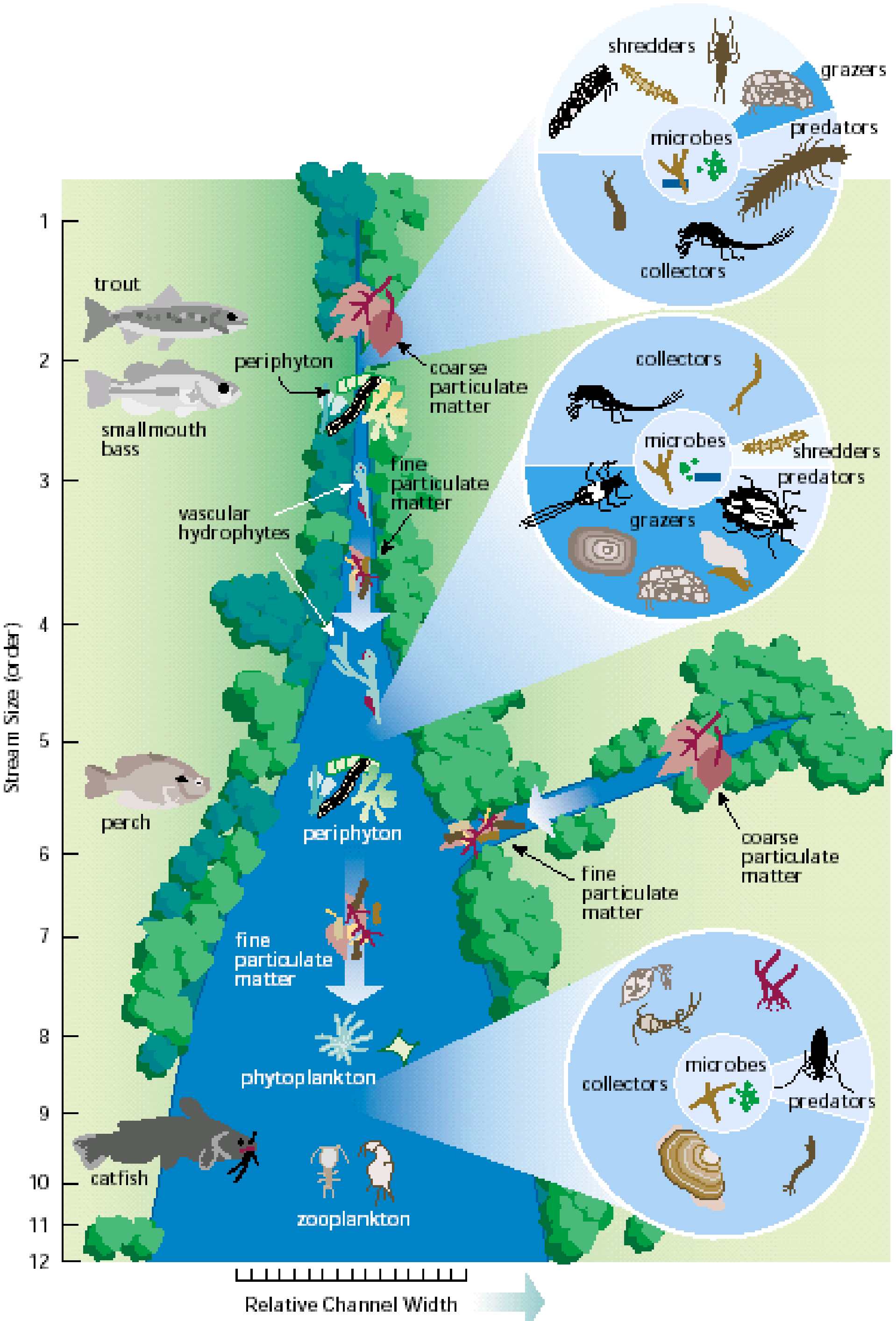
– Temperature

– Flow

– Substrate

– Food types

–But also water chemistry/ geology across regional landscape



Questions I addressed today:

1) Why do I study aquatic macroinvertebrates?

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?

3) How have insects adapted to life in water?

4) Are aquatic invertebrate populations dynamic variable over time?

5) What determines species richness and diversity – aquatic or terrestrial?

STROUD™ WATER RESEARCH CENTER

Questions I addressed today:

1) Why do I study aquatic macroinvertebrates?
   - Big – Macro
   - Ecologically Important
   - Numerous Species
   - Different Pollution Tolerances
   - Abundant

2) Why are insects (aquatic or terrestrial) ecologically and evolutionarily successfully?
   - Highly adaptable exoskeleton - locomotion, flight, water loss
   - Colonized terrestrial environment before chordates-competition
   - Small body size
   - Short generation time and high birth rate
   - Flight
   - Life history includes complete metamorphosis

3) How have insects adapted to life in water?
   - Physiological - osmoregulate, ventilation
   - Morphological - obtain O_2, endure current, move in water, collect food
   - Behavioral - obtain O_2, ventilation, food

4) Are aquatic invertebrate populations dynamic variable over time?
   - Aquatic insect life histories
   - Temperature

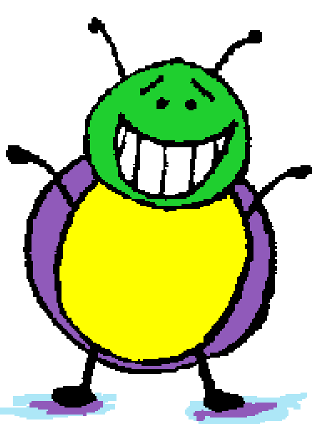
5) What determines species richness and diversity – aquatic or terrestrial?
   - Diversity of conditions
   - Deviation from normal
   - Time since disturbance

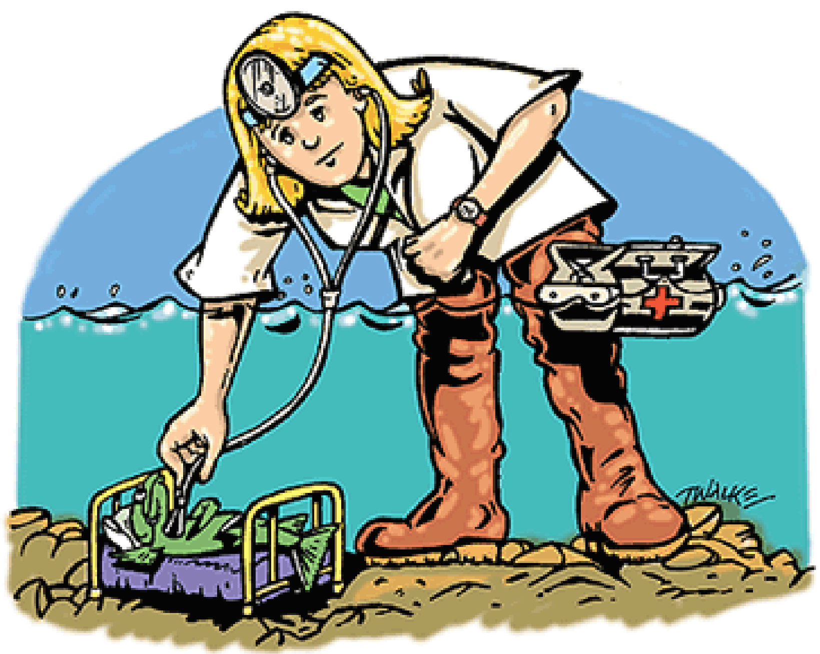
STROUD™
WATER RESEARCH CENTER

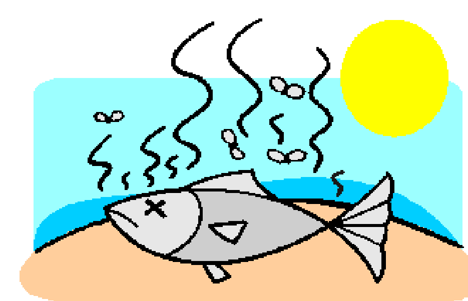
In pollution monitoring,

Presence tells you something

Conspicuous absence also tells you something





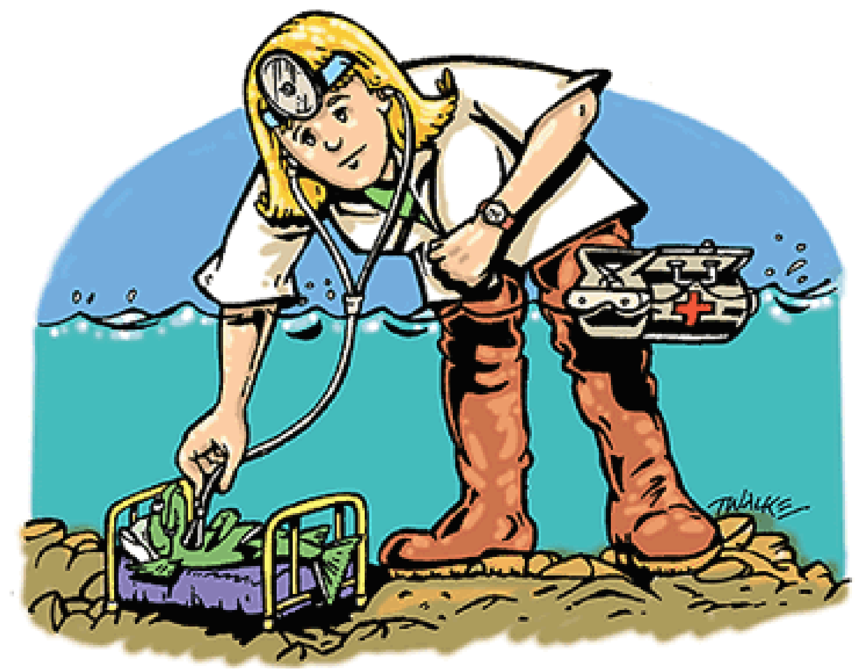


In pollution monitoring,

Presence tells you something

Conspicuous absence also tells you something

Use caution –
– absence could reflect natural phenomena such as season, location, or microhabitat



John K. Jackson, Ph.D.
Senior Research Scientist
Stroud Water Research Center

jkjackson@stroudcenter.org
610.268.2153 x226