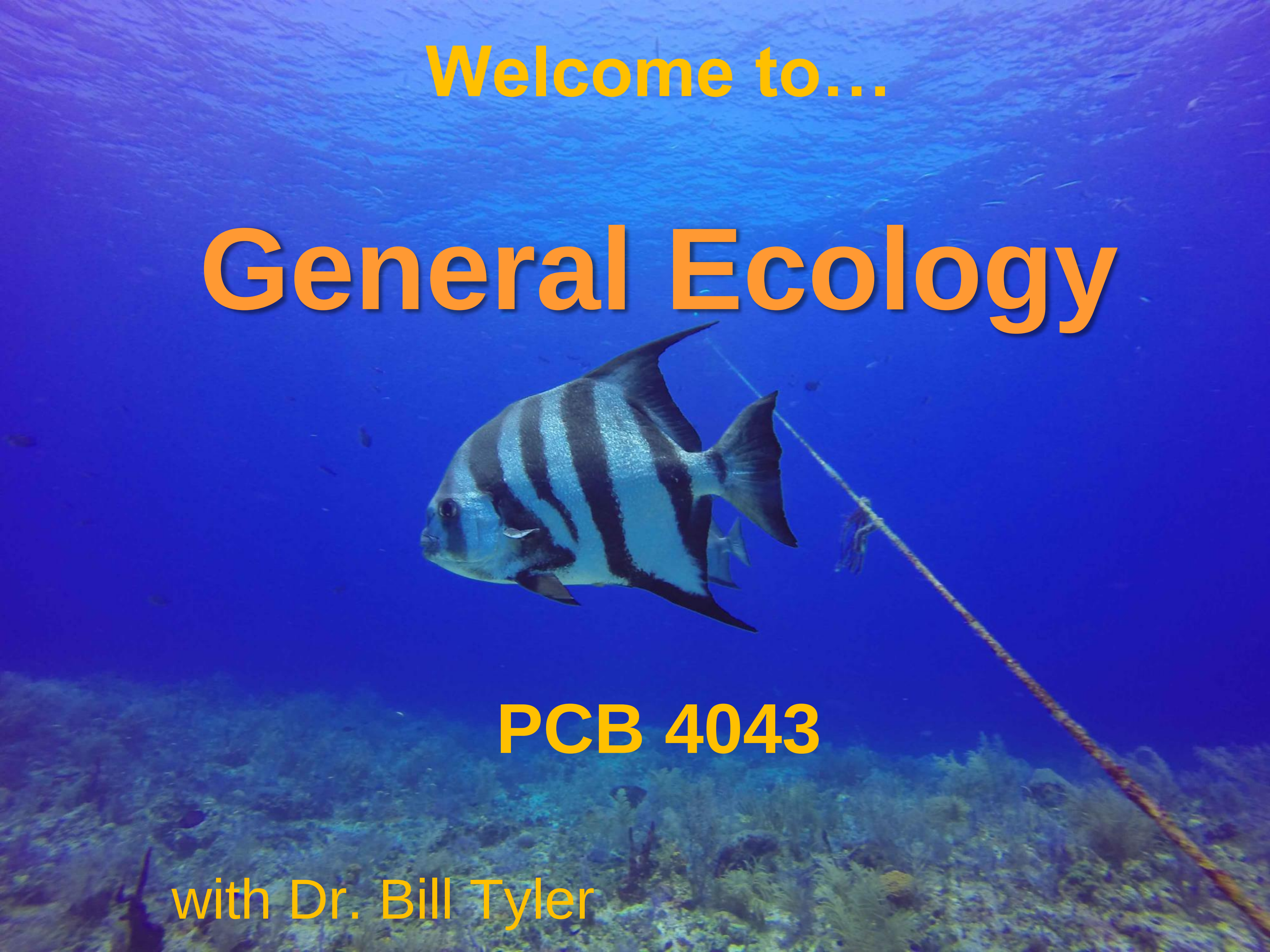
Welcome to…

General Ecology



PCB 4043

with Dr. Bill Tyler

1 Introduction: The Web of Life

Chapter 1 The Web of Life

- *Case Study*: Deformity and Decline in Amphibian Populations
- CONCEPT 1.1 Events in the natural world are interconnected.
- CONCEPT 1.2 Ecology is the scientific study of interactions between organisms and their environment.
- CONCEPT 1.3 Ecologists evaluate competing hypotheses about natural systems with observations, experim
- *Case Study Revisited*

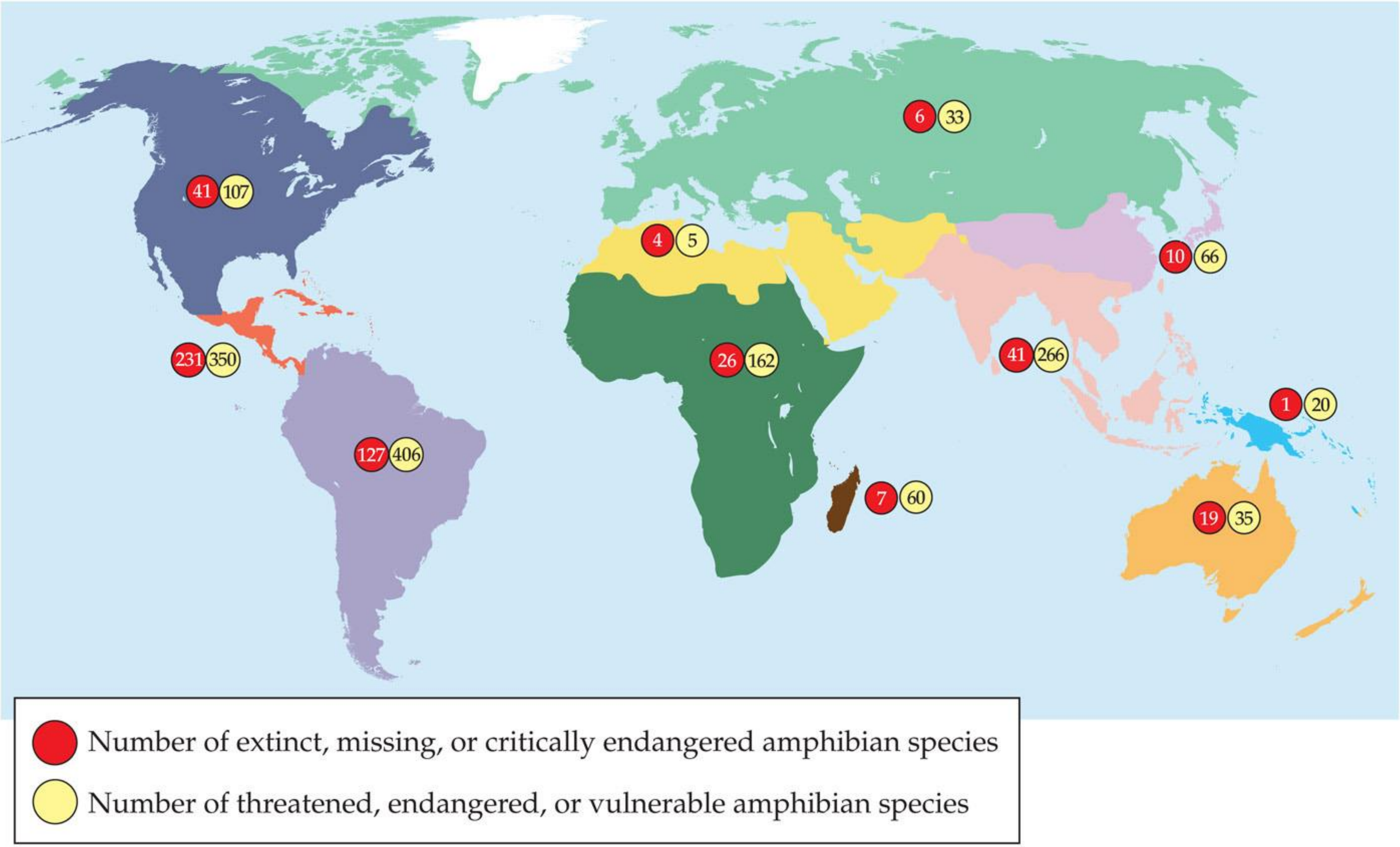
- *Case Study*: Deformity and Decline in Amphibian Populations
- Connections in Nature
- Ecology
- Answering Ecological Questions
- *Case Study Revisited*
- *Connections in Nature*: Mission Impossible?

Case Study: Deformity and Decline in Amphibian Populations

Figure 1.1 Deformed Leopard Frogs

- 1995, elementary and middle school students discovered deformed leopard frogs
- High incidence of deformities in some 60 species of amphibians
    - Declining populations of amphibians worldwide since late 1980s

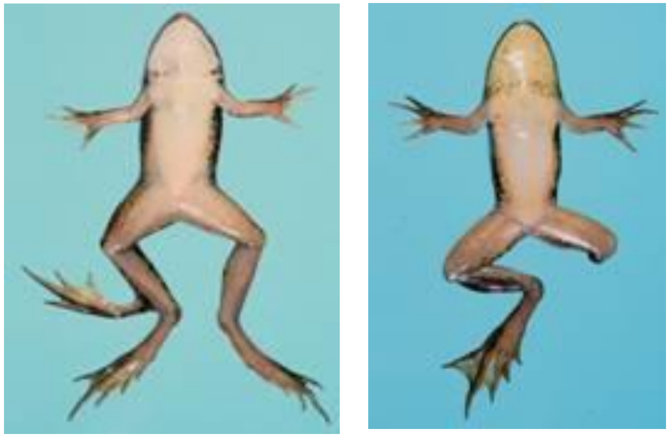
Figure 1.2 Amphibians in Decline



ECOLOGY 3e, **Figure 1.2**

Deformity and Decline in Amphibian Populations: A Case Study

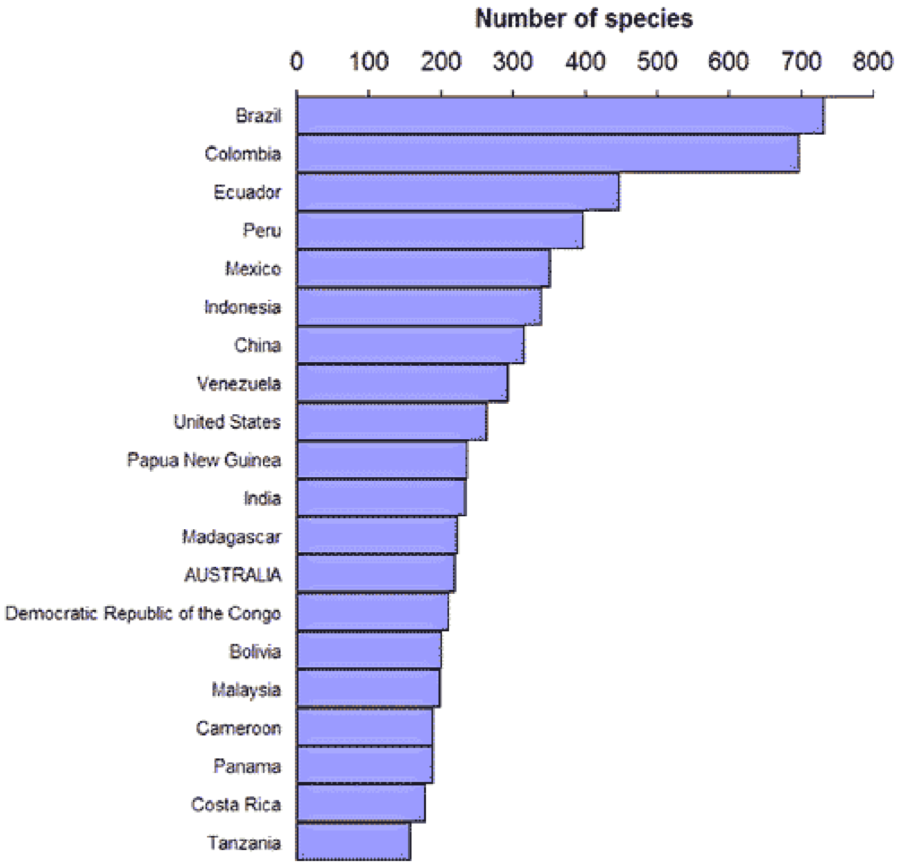
- Amphibians are "biological indicators" of environmental problems.
  - Skin is permeable; pollutant molecules can pass through easily.
  - Eggs have no protective shell.
  - They spend part of their life on land and part in water—exposed to pollutants and UV in both environments.

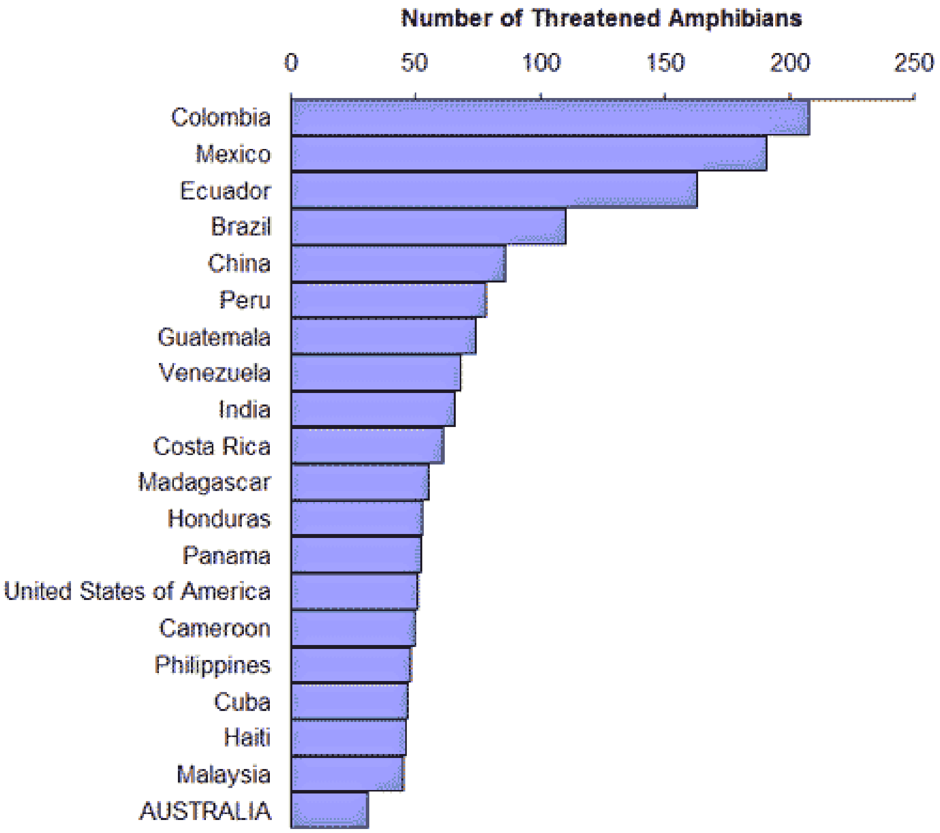


Examples of some amphibian deformities in northern leopard frogs

http://www.nwhc.usgs.gov/disease_information/amphibian_malformation_and_decline/index.jsp

Numbers of amphibian species worldwide and threatened



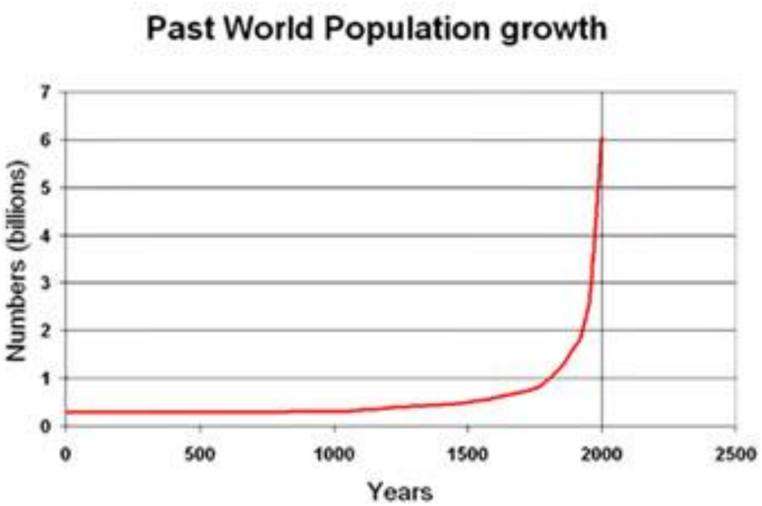


http://www.environment.gov.au/soe/2006/publications/drs/indicator/70/index.html http://www.learner.org/courses/envsci/visual/img_med/past_pop_growth.jpg

Introduction

Humans have enormous impact on the planet

- Transformed nearly half of land; even vast oceans
- Must understand how natural systems work



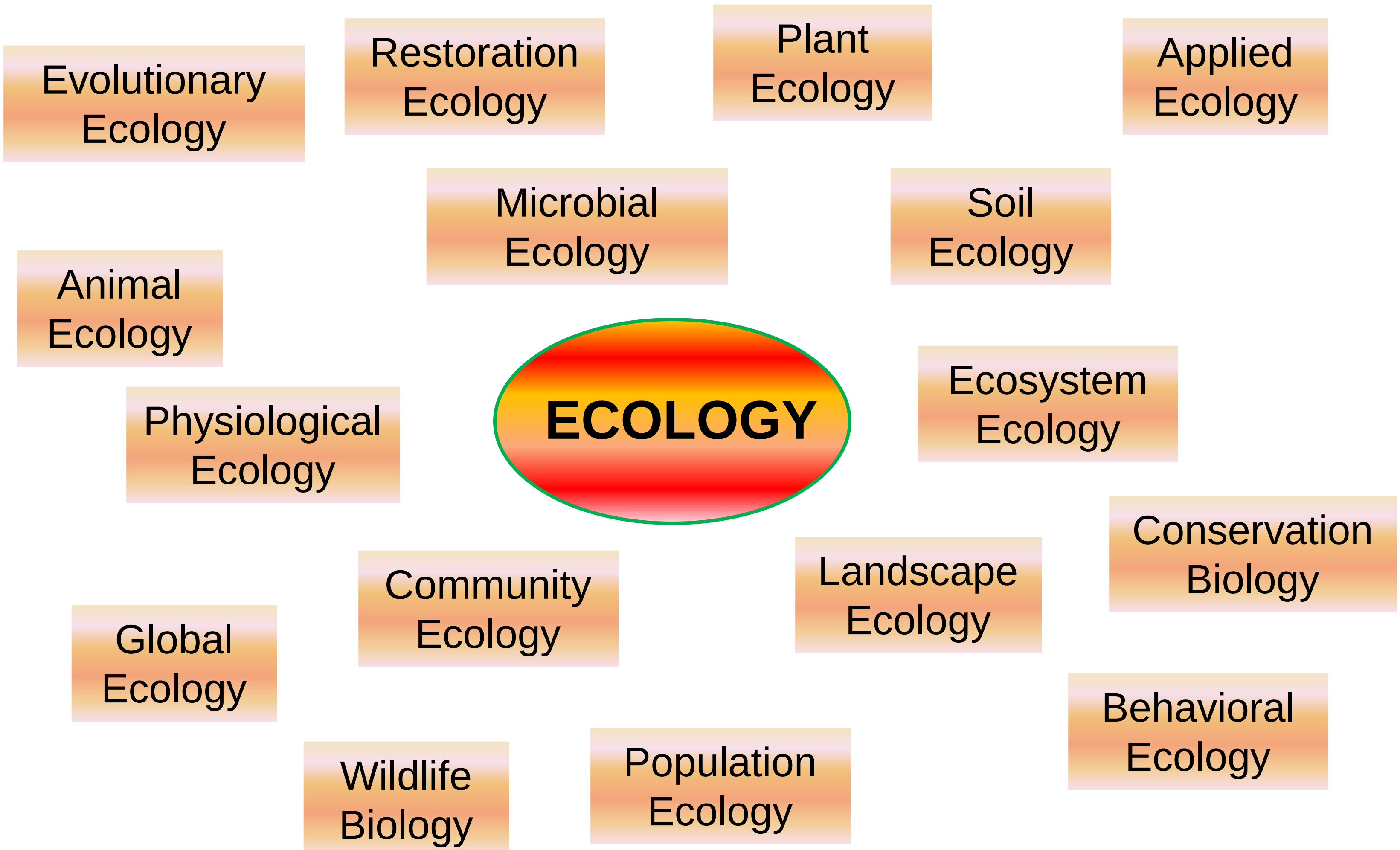
Ecology

- Scientific study of how organisms affect — and are affected by — other organisms and their environment
- Interactions between organisms and their environment (includes other organisms)

Clear cutting of timber

http://www.satyamag.com/sat.site.images/clear-cut.jpg

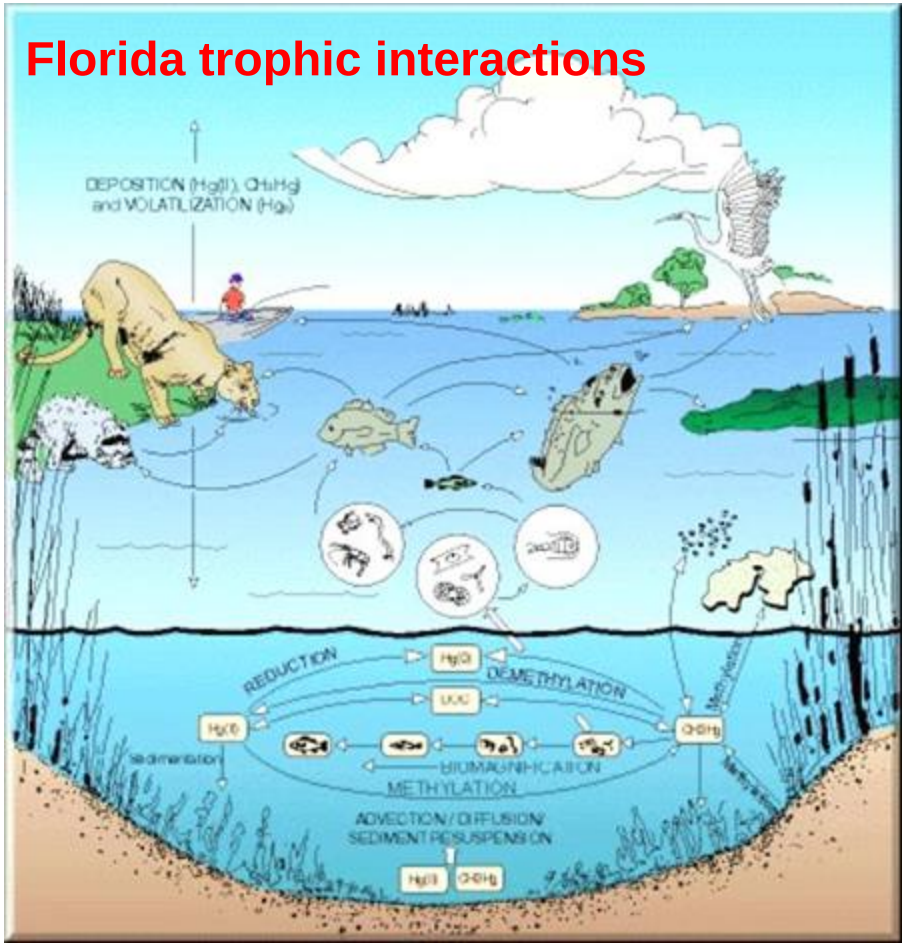
Ecology is an interdisciplinary approach



Concept 1.1: Events in the natural world are interconnected.

- Even species that do not interact directly can be connected by shared environmental features

- Ecologists ask questions about the natural world to understand these connections



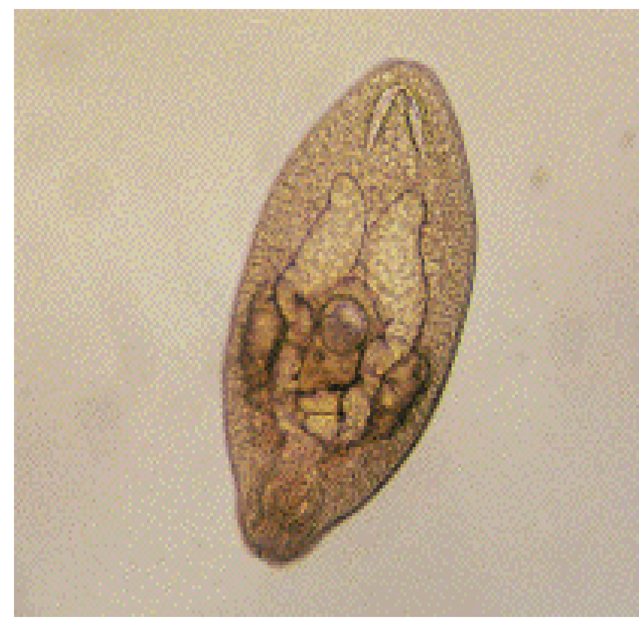
http://www.mercuryinschools.uwex.edu/lib/images/curriculum/florida_food_web.jpg http://northislandexplorer.com/amphibians/pacifictreefrog.jpg

Connections in Nature

Observations of Pacific tree frogs suggested that *parasites can cause deformities*

- **Sessions & Ruth, 1990**: Implanted glass beads mimics effect of *Ribeiroia ondatrae* cysts, a trematode flatworm, in different frog species (*Xenopus*)

Lab Experiment



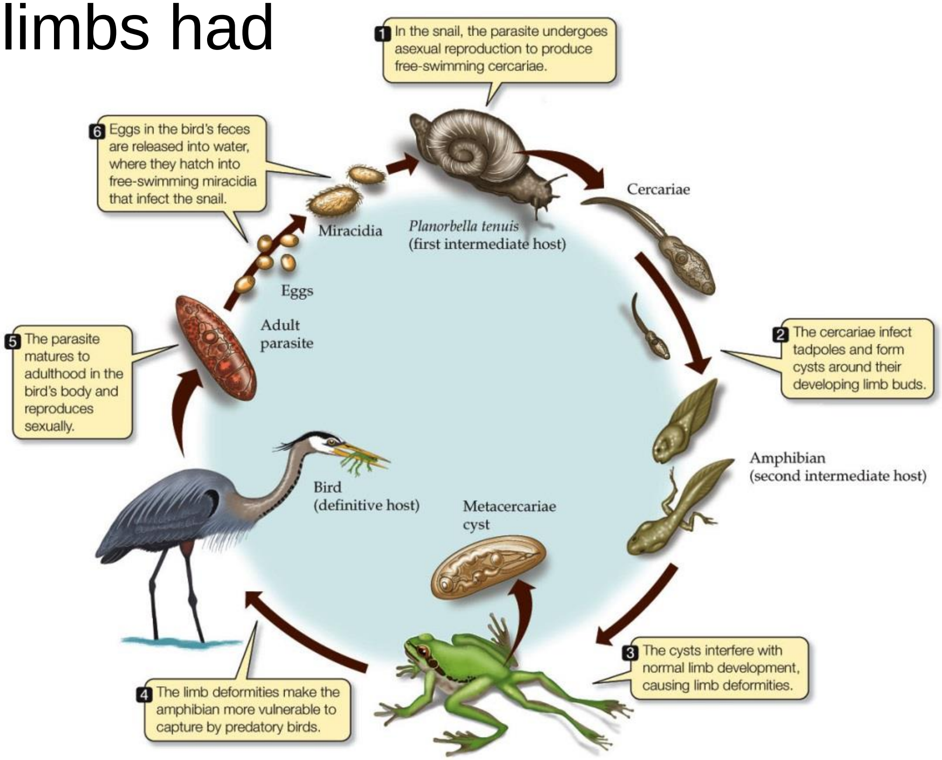
http://www.stockpix.com/image/2857.jpg

http://www.sci.sdsu.edu/classes/biology/bio588/Metacercaria20.gif

Connections in Nature

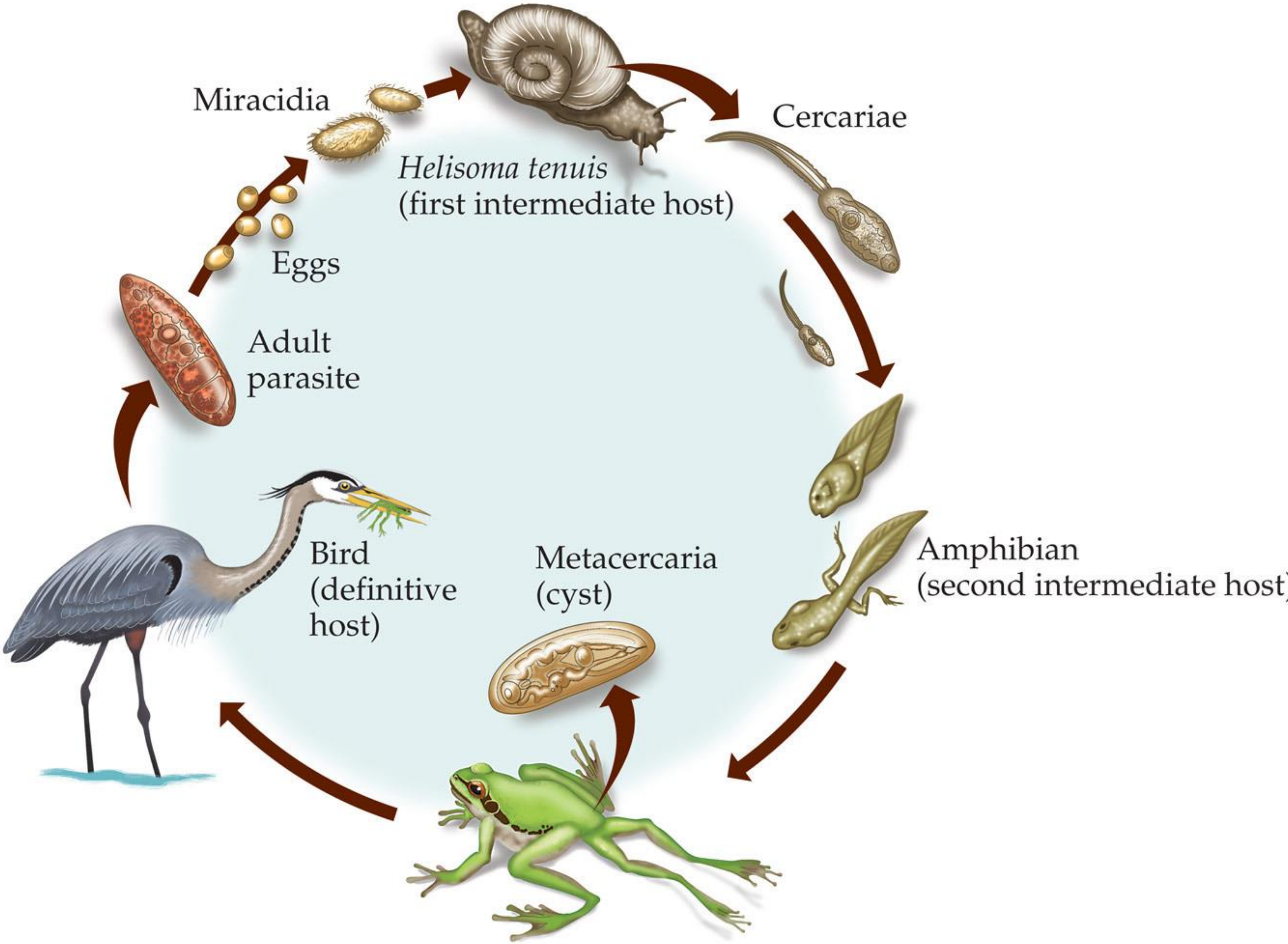
- **Johnson et al**:
  - Deformities of Pacific tree frogs occurred only in ponds which also had an aquatic snail, *Helisoma tenuis*, the intermediate host of the parasite
  - All frogs with deformed limbs had *Ribeiroia* cysts.

Comparative Field Study



ECOLOGY, Figure 1.3

Figure 1.3 The Life Cycle of *Ribeiroia*

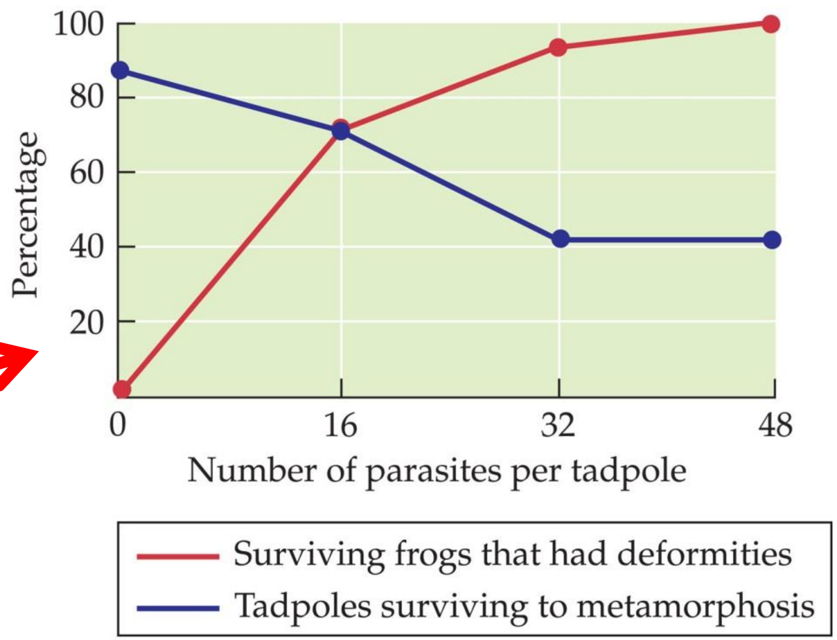


***ECOLOGY 3e*, Figure 1.3**

A **controlled experiment** to test hypothesis that *Ribeiroia* parasites caused deformities (Johnson et al, 1999)

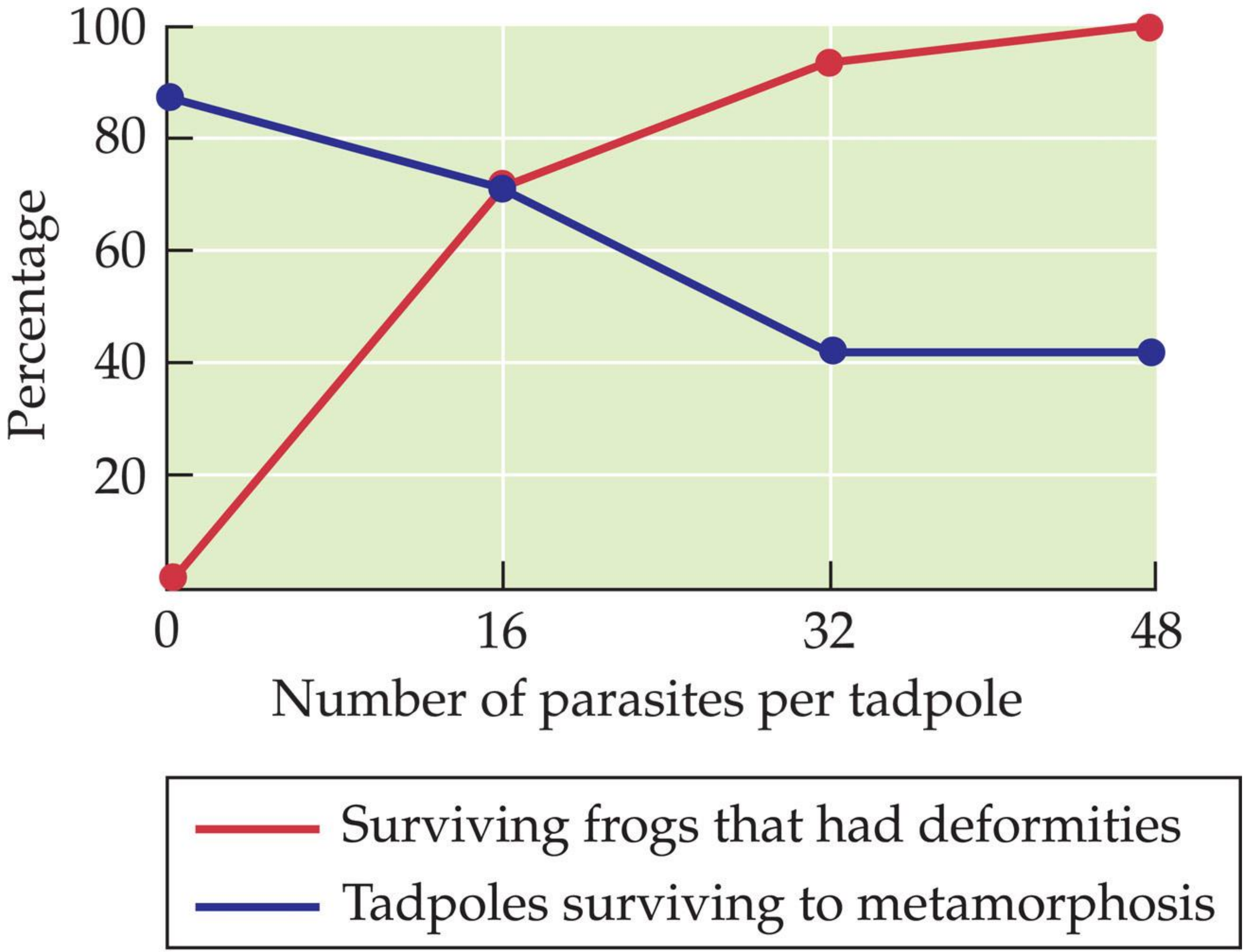
- Tree frog eggs were exposed to *Ribeiroia* parasites in the lab
- Four treatments: 0 (control group), 16, 32, or 48 *Ribeiroia* parasites
- As parasite load increased, survival decreased and deformities in survivors increased
- Supported by other field work

Controlled Lab Experiment



ECOLOGY 3e, Figure 1.4

Figure 1.4 Parasites Can Cause Amphibian Deformities



ECOLOGY 3e, Figure 1.4

Kiesecker (2002) conducted a field experiment:

- Six ponds, three with pesticide contamination
- Added tadpoles to cages
- Six cages in each pond
  - Three with mesh size allowing parasites to enter
  - Three with mesh blocking parasites ("*exclusion cage*")

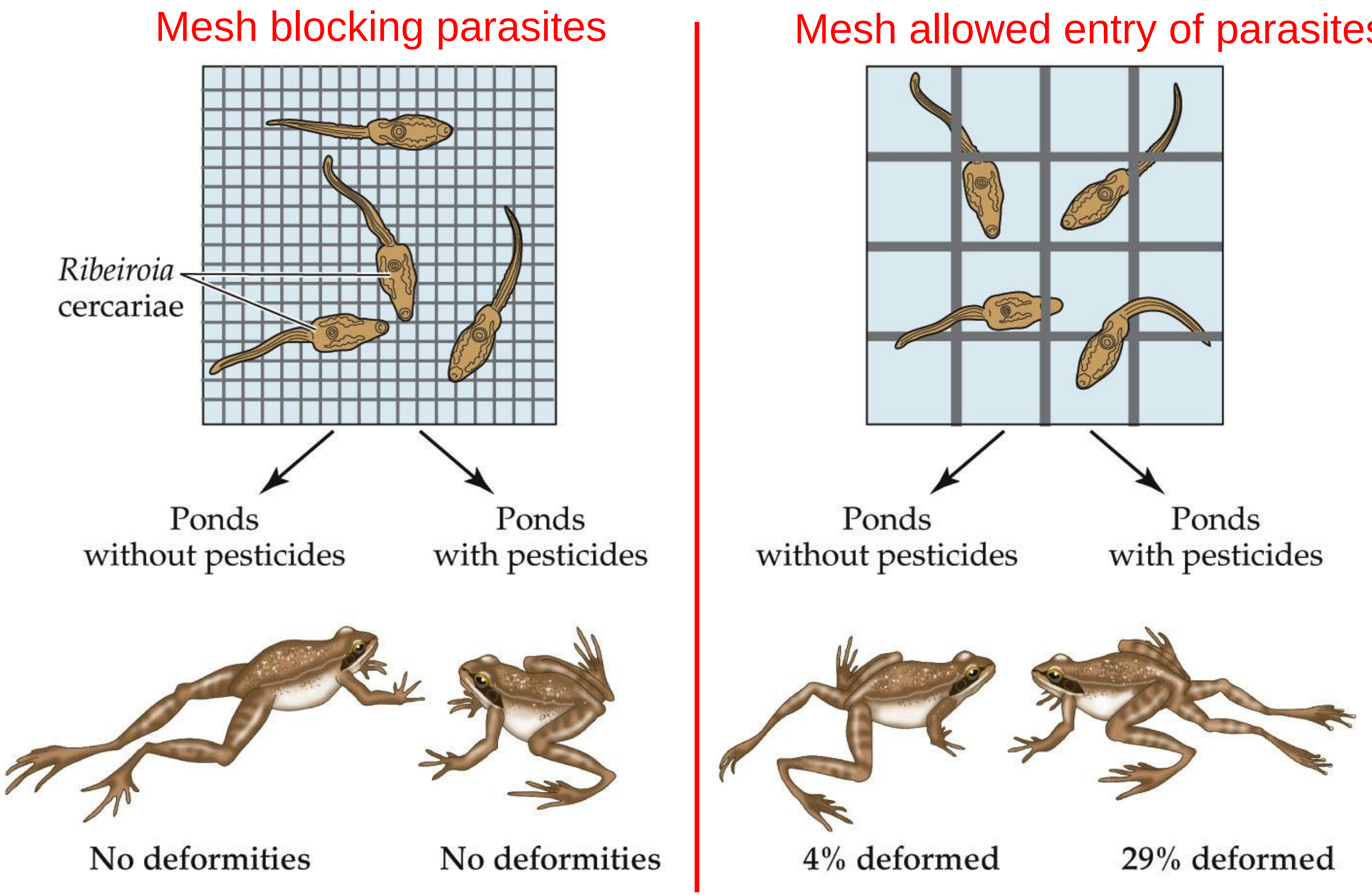
Manipulative Field Experiment

ECOLOGY, Figure 1.5 (Part 1)

Figure 1.5 Do *Ribeiroia* and Pesticides Interact in Nature? (Part 1)

ECOLOGY, **Figure 1.5 (Part 1)**

Figure 1.5 Do *Ribeiroia* and Pesticides Interact in Nature? (Part 2)

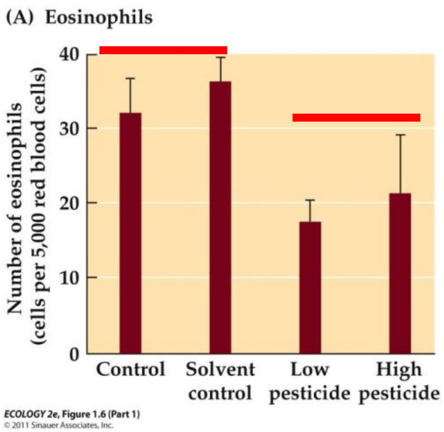


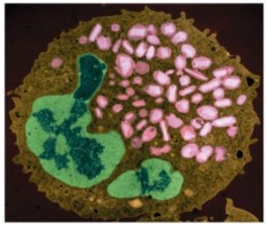
- Pesticides alone had no effect on deformities
  - Pesticides significantly weakened resistance to parasites

Lab Experiment

Next hypothesis: Pesticides decrease frog's ability to resist parasite infection (Kiesecker, 2002)

- Another lab experiment: Infected tadpoles reared in presence of pesticides
  - had fewer white blood cells (indicating a suppressed immune system) and…
  - higher rate of *Ribeiroia* cyst formation





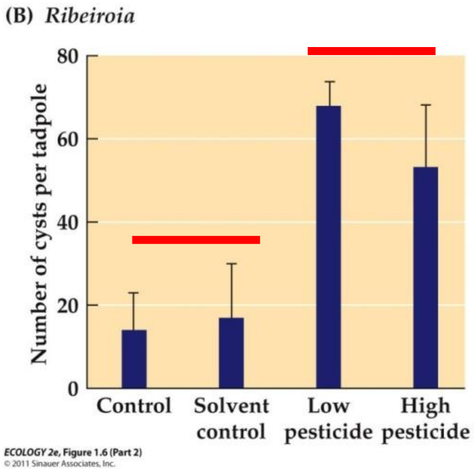
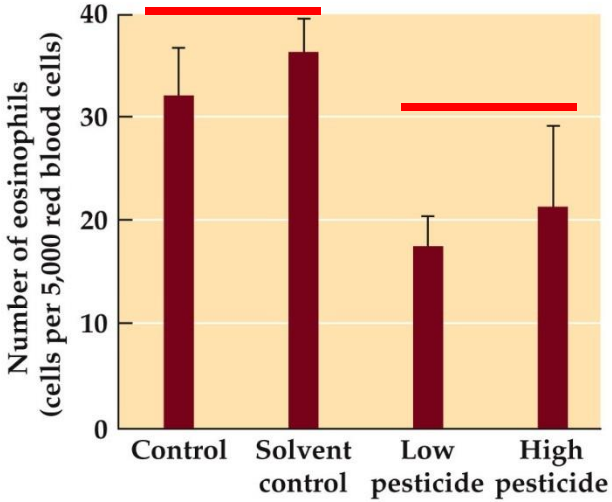
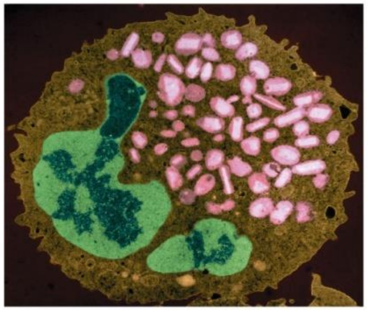


Figure 1.6 Pesticides May Weaken Tadpole Immune Systems (Part 1)

(A) Eosinophils



ECOLOGY 2e, Figure 1.6 (Part 1)

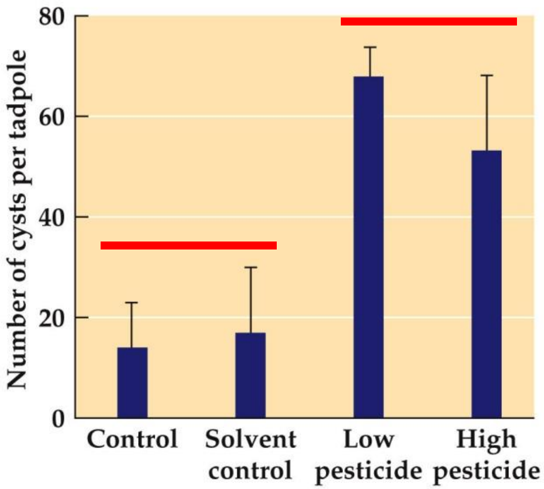


Lab Experiment with two controls…to test effect of pesticides when parasites are present

Experiment with two controls (a & b)

a) Control = only parasites
b) Parasites & solvent only (check for effect of solvent ["*sham*"] → no effect)
c) Parasites & low pesticide in solvent
d) Parasites & high pesticide in solvent

(B) *Ribeiroia*

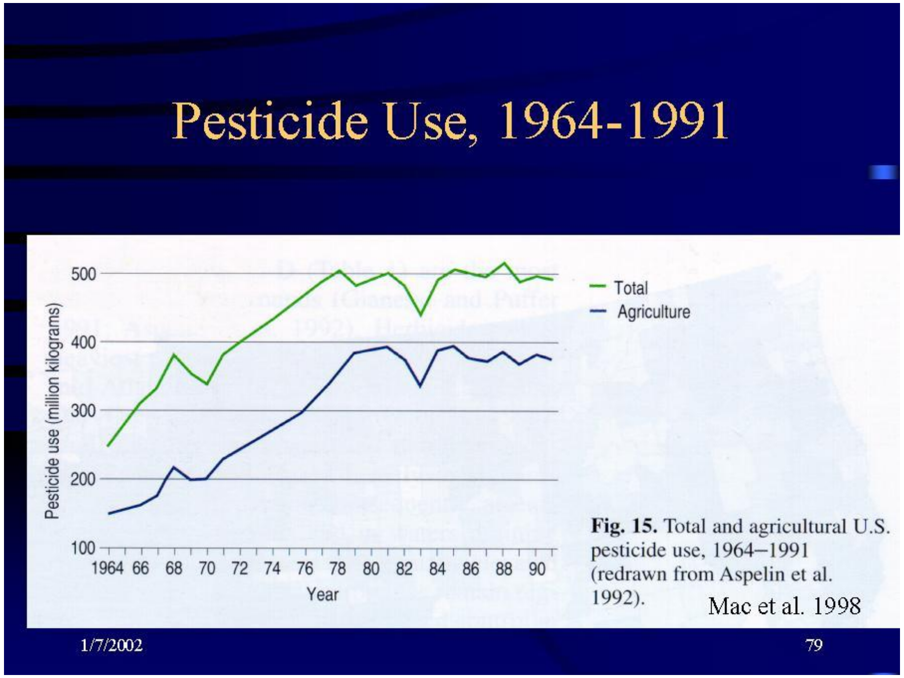


ECOLOGY 2e, Figure 1.6 (Part 2)

Unintended effects via interconnections:

Schmitt CJ. 1998. Environmental Contaminants. Pages 131-165 in Mac MJ, Opler PA, Puckett Haecker CE, Doran PD. Status and trends of the nation's biological resources. U.S. Department of the Interior, U.S. Geological Survey, Reston, Va.

- Synthetic pesticide use began in 1930s and has increased dramatically since
  - Amphibian exposure to pesticides has also increased.
  - Any action (increased pesticide use by people) can potentially have unanticipated side effects (more frequent deformities in amphibians).



http://www.fs.fed.us/ne/delaware/biotrends/trends79.JPG

Connections in Nature

http://msnbcmedia2.msn.com/j/msnbc/Components/Photos/050614/050614_algae_hmed_6a.hmedium.jpg

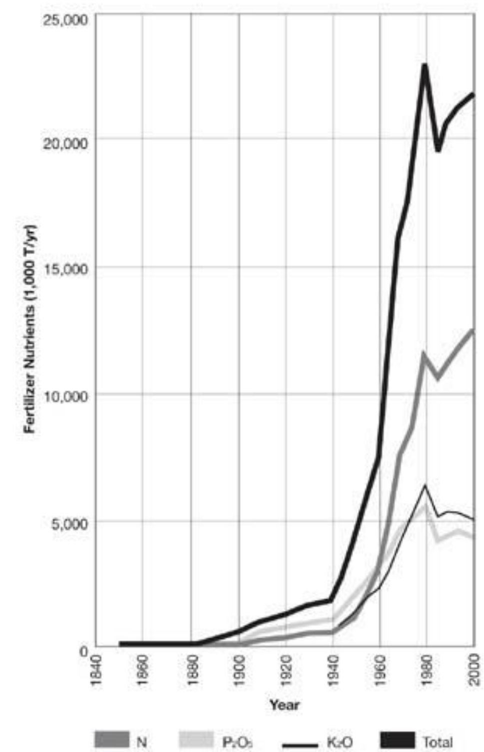
http://www.msnbc.msn.com/id/8214501/

Long-term impacts (algal blooms) seen on lakes from fertilizer, manure

Fertilizer use may also be a factor:

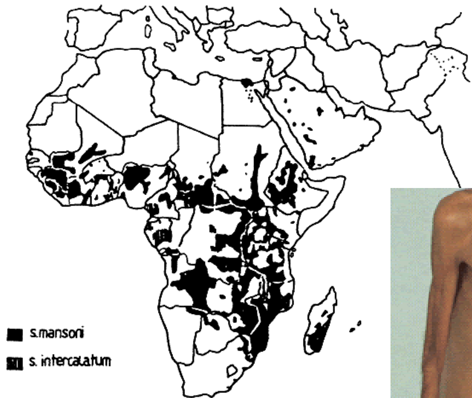
- Fertilizer in runoff to ponds increases algal growth
- Snails that harbor *Ribeiroia* parasites eat algae
- Greater numbers of snails result in greater numbers of *Ribeiroia* parasites

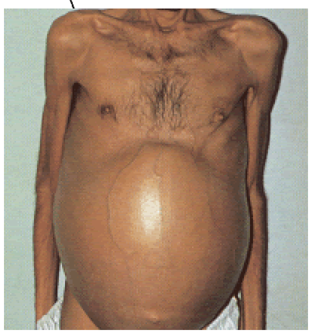
Figure 2. The use of fertilizer in the United States over the past 150 years.

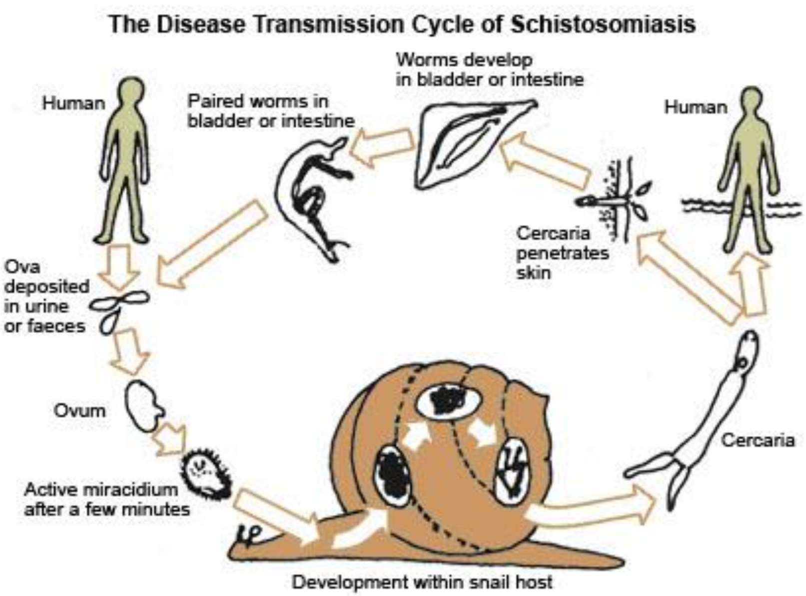


http://cropsoil.psu.edu/extension/facts/img/af38afig2.jpg

Schistosomiasis in Africa







Many human actions have also increased human health risks

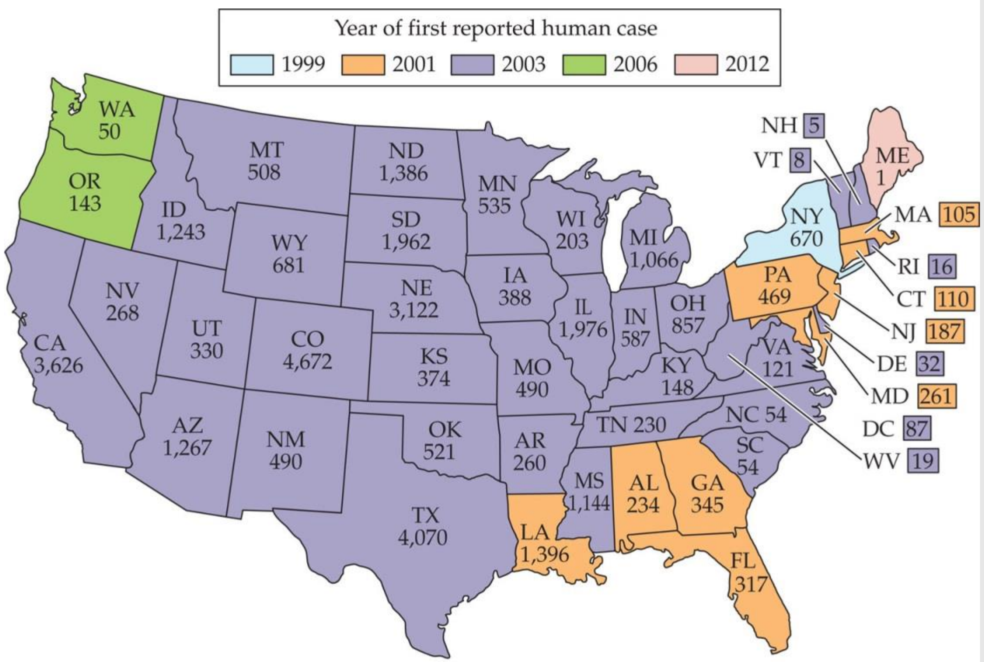
- Damming rivers in Africa increases habitat for snails that carry schistosomiasis
- New diseases (e.g. AIDS, Lyme disease, Hantavirus, Ebola, & West Nile fever) may be related to human activities
- Humans expanding into more wilderness areas, contacting more animal hosts increases exposure to “novel” viruses

http://www.wikieducator.org/images/4/4c/Schistosomiasis.jpg

http://www.universityscience.ie/imgs/scientists/shistosomiasis.gif

Figure 1.7 Rapid Spread of a Deadly Disease

- West Nile virus spread from New York City (point of entry) to 45 states.
  - Birds are primary host and mosquitoes are vectors
  - Mammals (including humans) are “dead-end” carriers



ECOLOGY 3e, Figure 1.7

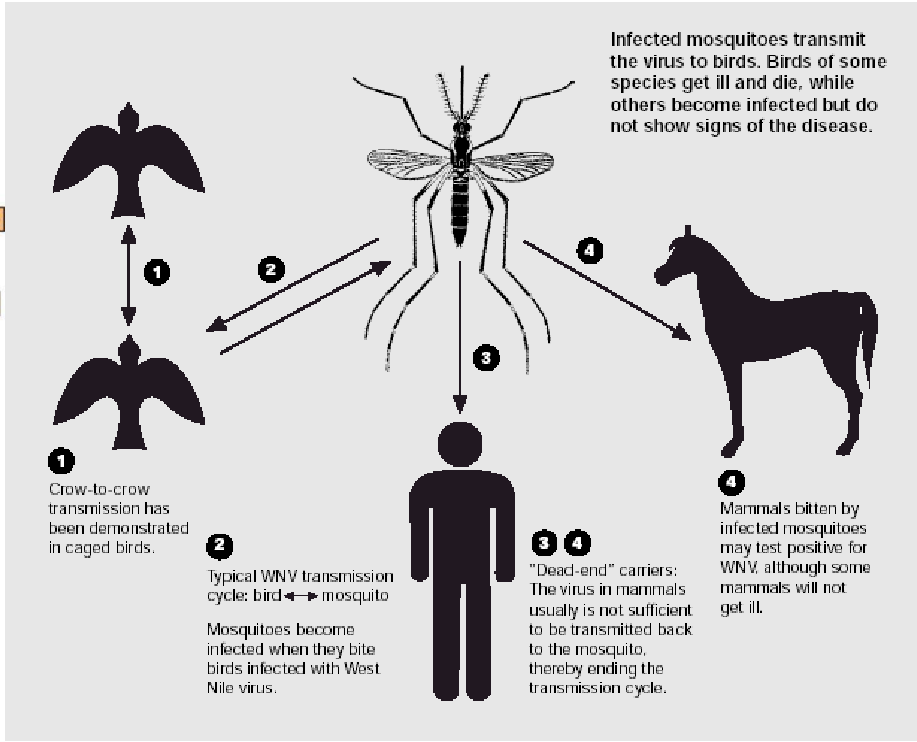
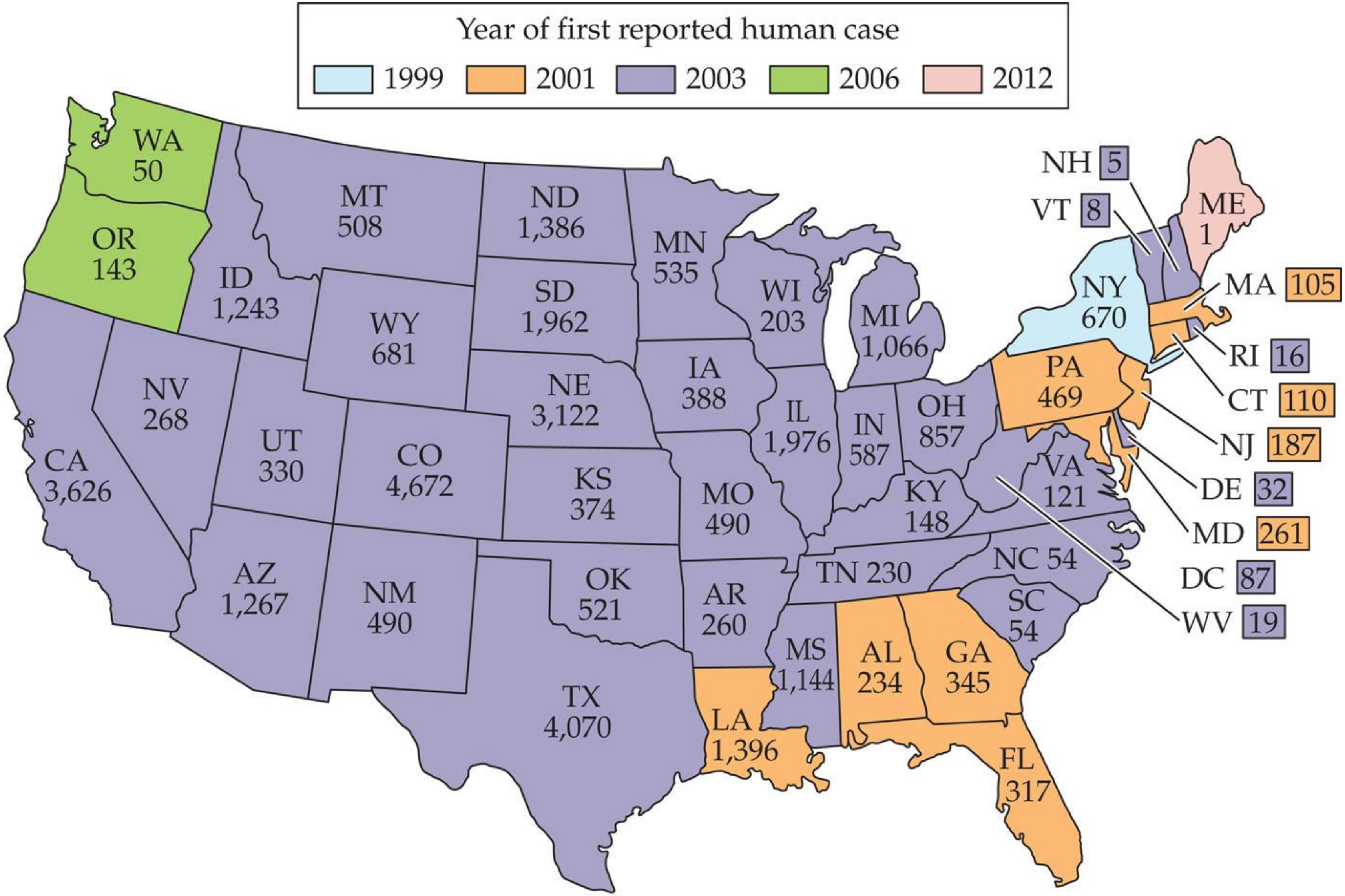


Figure 1.7 Rapid Spread of a Deadly Disease



ECOLOGY 3e, **Figure 1.7**

Concept 1.2: Ecology is the scientific study of interactions between organisms and their environment.

Jump to Slide #43

On Your Own

Ecology is a branch of biology that combines information about organisms and the physical world

Environmental science is even more interdisciplinary

- incorporates concepts from
  - the natural sciences (ecology and physical sciences) and…
  - the social sciences (economics, policy/law, ethics)
  - focuses on solutions to environmental problems

Early (*and out-dated*) ecological views:

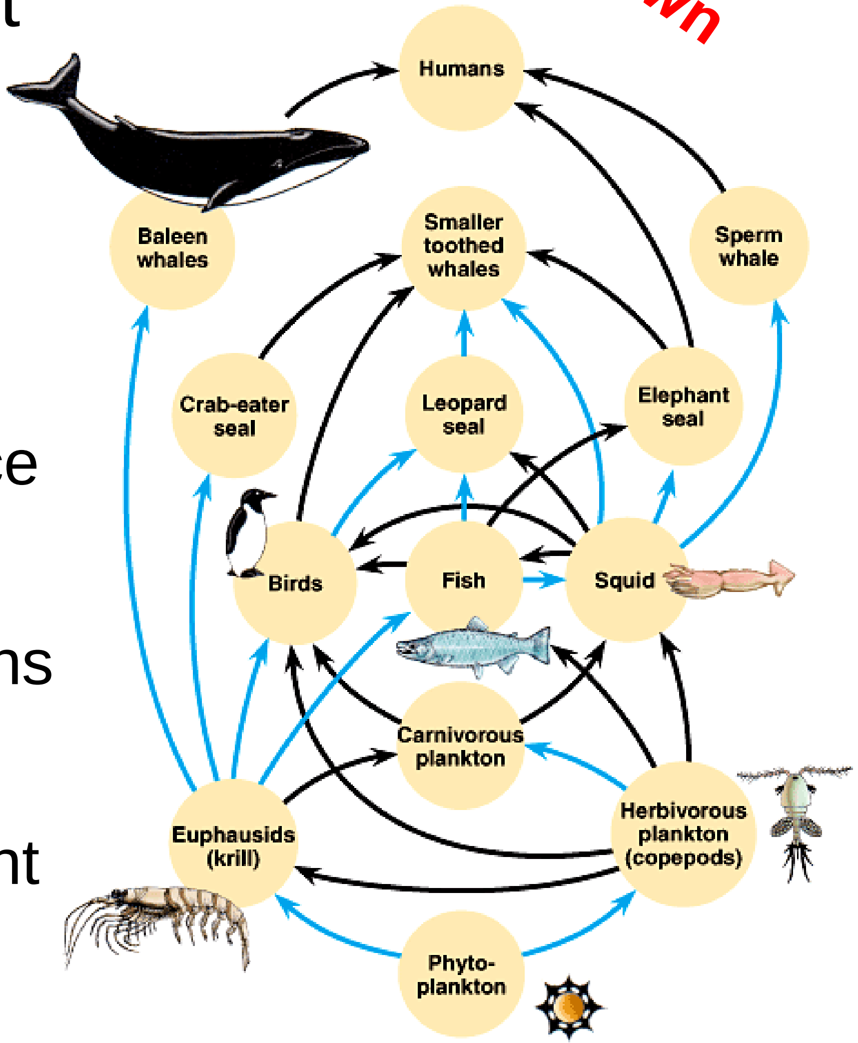
On Your Own

- A “balance of nature”
  - natural systems are stable and tend to return to an original state after disturbance
- Each species has a distinct role to play in maintaining that balance

On Your Own

Ecologists now recognize that ecological *interactions are much more complex...*

- Natural systems do not necessarily return to their original state after a disturbance (“**tipping points**”).
- Seemingly random perturbations can play an important roles.
- Evidence suggests that different species often respond in different ways to changing conditions.

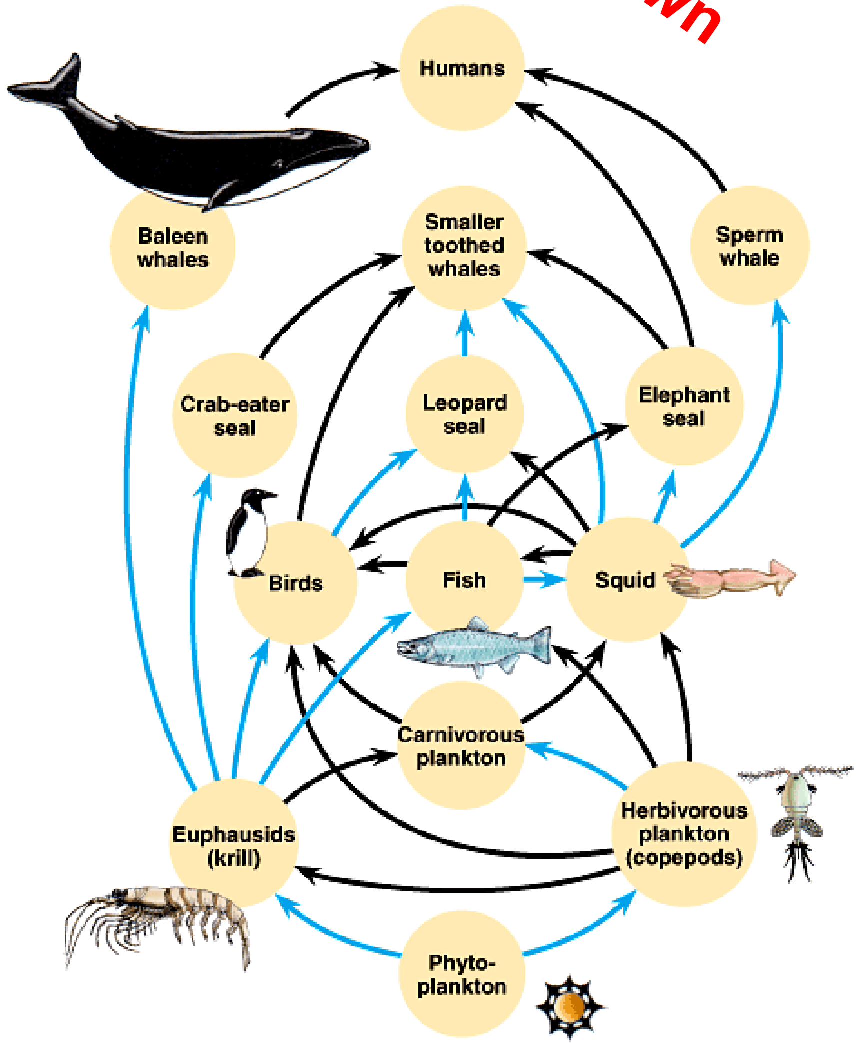


http://io.uwinnipeg.ca/~simmons/16cm05/1116/53-11-AntarcticFoodWeb-L.gif

On Your Own

One view that has stood the test of time…

- Events in nature are interconnected…
- A change in one part of an ecological system can alter other parts of that system.



http://io.uwinnipeg.ca/~simmons/16cm05/1116/53-11-AntarcticFoodWeb-L.gif

TABLE 1.1 (*Part 1*)

Some Ecological Maxims

LOOK THIS OVER

1. You can never do just one thing.
   Organisms interact with one another and with their physical environment. As a result, events in nature are connected, and what affects one organism or place can affect others as well.

2. Everything goes somewhere.
   There is no "away" into which waste materials disappear.

3. No population can increase in size forever.
   There are limits to the growth and resource use of every population, including our own.

4. There is no free lunch.
   An organism's energy and resources are finite, and increasing inputs into one function (such as reproduction) results in a trade-off in which there is a loss for other functions (such as growth).

TABLE 1.1 (*Part 2*)

Some Ecological Maxims

LOOK THIS OVER

5. Evolution matters.
   Organisms evolve or change over time—it is a mistake to view them as static. Evolution is an ongoing process because organisms continually face new challenges from changes in both the living and nonliving components of their environment.

6. Time matters.
   Ecosystems change over time. When we look at the world as we know it, it is easy to forget how past events may have affected our present, and how our present actions may affect the future.

7. Space matters.
   Abiotic and biotic environmental conditions can change dramatically from one place to another, sometimes across very short distances. This variation matters because organisms are simultaneously influenced by processes acting at multiple spatial scales, from local to regional to global.

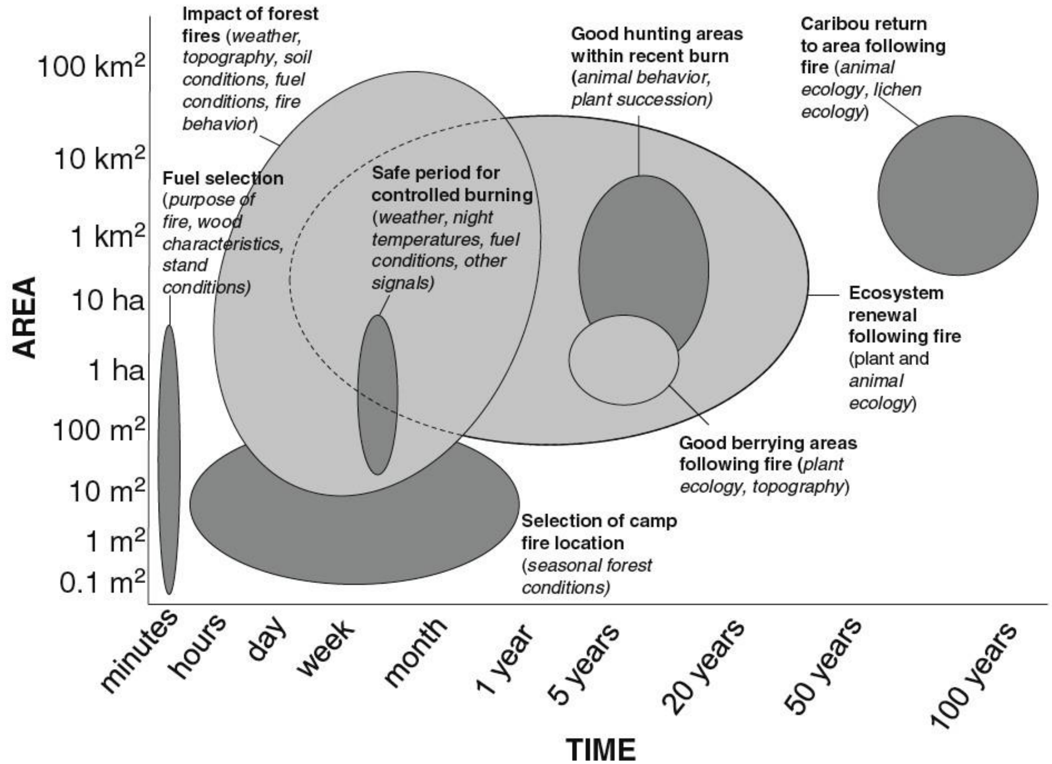
8. Life would be impossible without species interactions.
   Species depend on one another for energy, nutrients, and habitat.

ECOLOGY 3e, Table 1.1 (Part 2)

On Your Own

Ecologists must select appropriate **scales** of study.

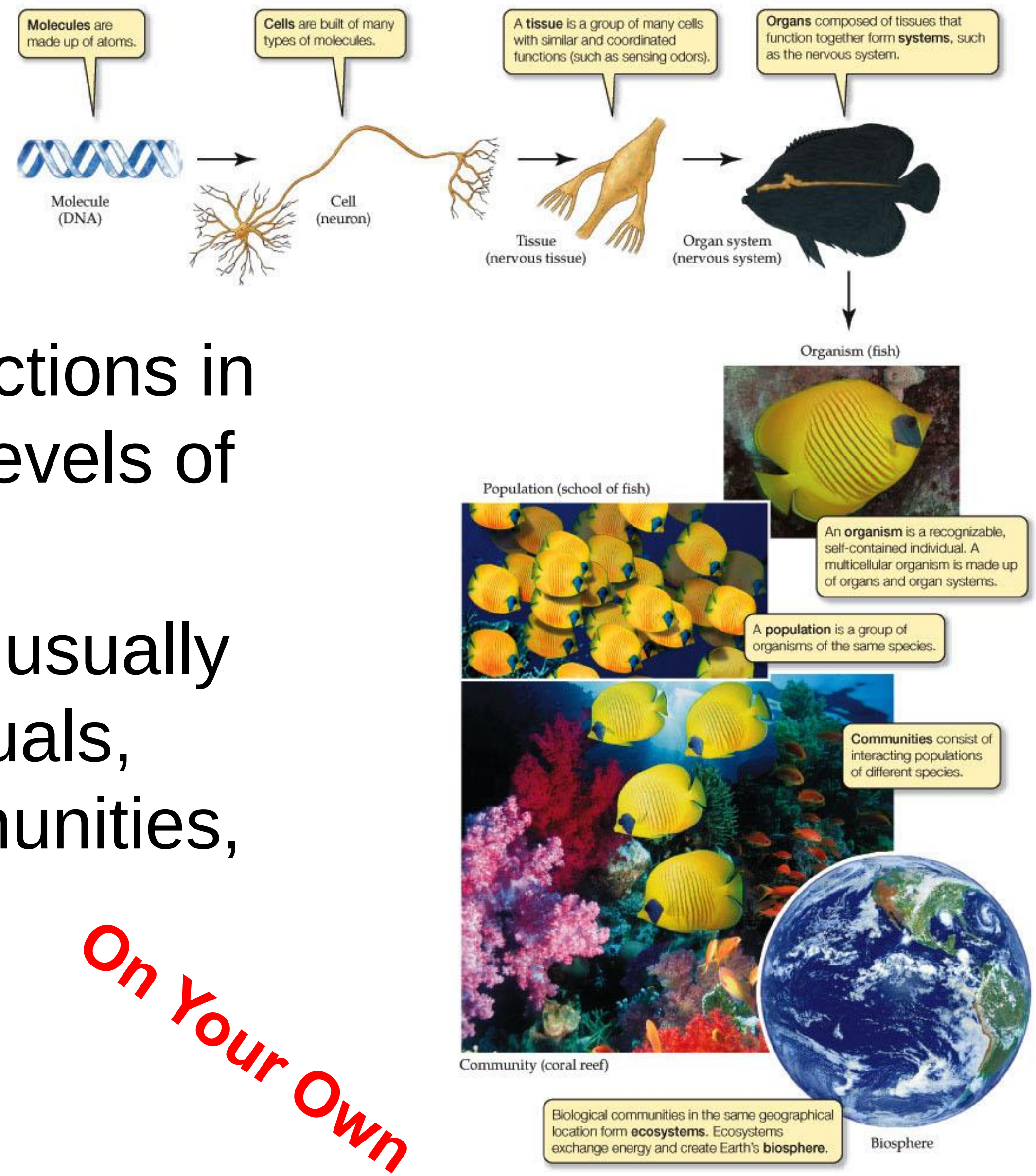
- **Spatial scales**:
  - Small—soil microorganisms
  - Large—atmospheric pollutants
- **Temporal scales**:
  - Short—leaf response to sunlight
  - Long—how species change over geologic time



http://rs.resalliance.org/2010/09/28/fire-and-the-anishinaabe/

Ecologists study interactions in nature across many levels of organization.

- Ecological studies usually emphasize individuals, populations, communities, or ecosystems.

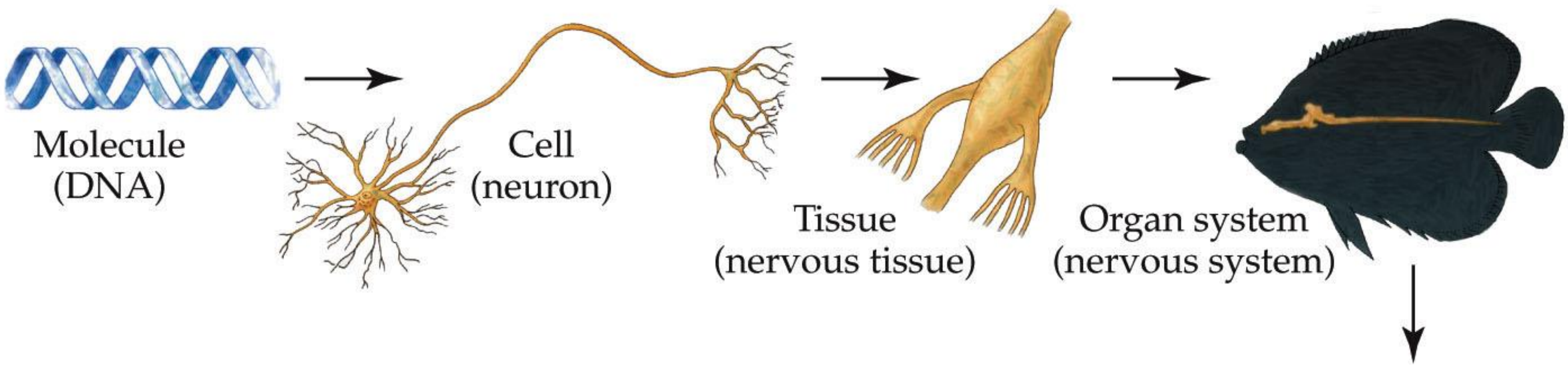


On Your Own

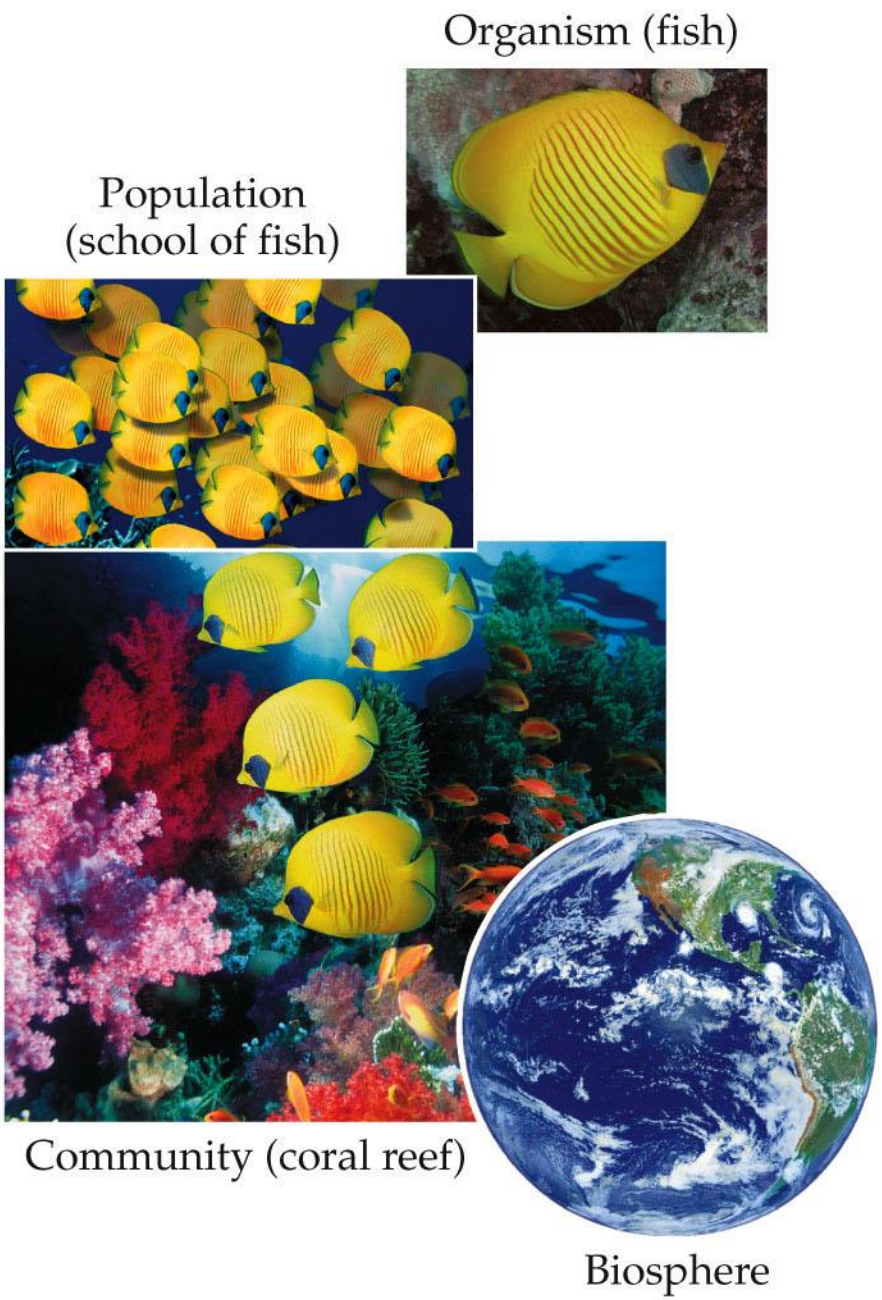
***ECOLOGY*, Figure 1.8**

Figure 1.8 Levels of Biological Organization (Part 1)

On Your Own



ECOLOGY, Figure 1.8 (Part 1)



On Your Own

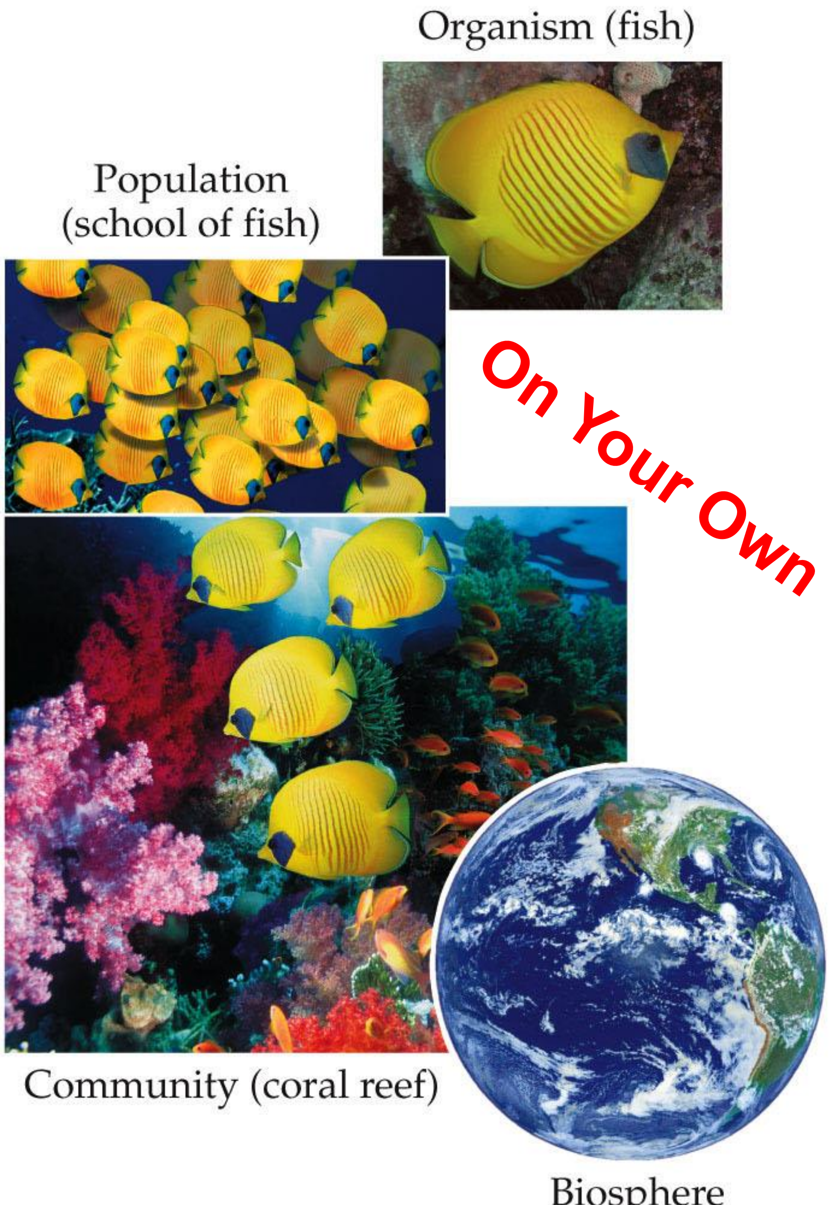
ECOLOGY, Figure 1.8 (Part 2)

A **population:**

- Group of individuals of a single species that live in a particular area and interact with one another

A **community**:

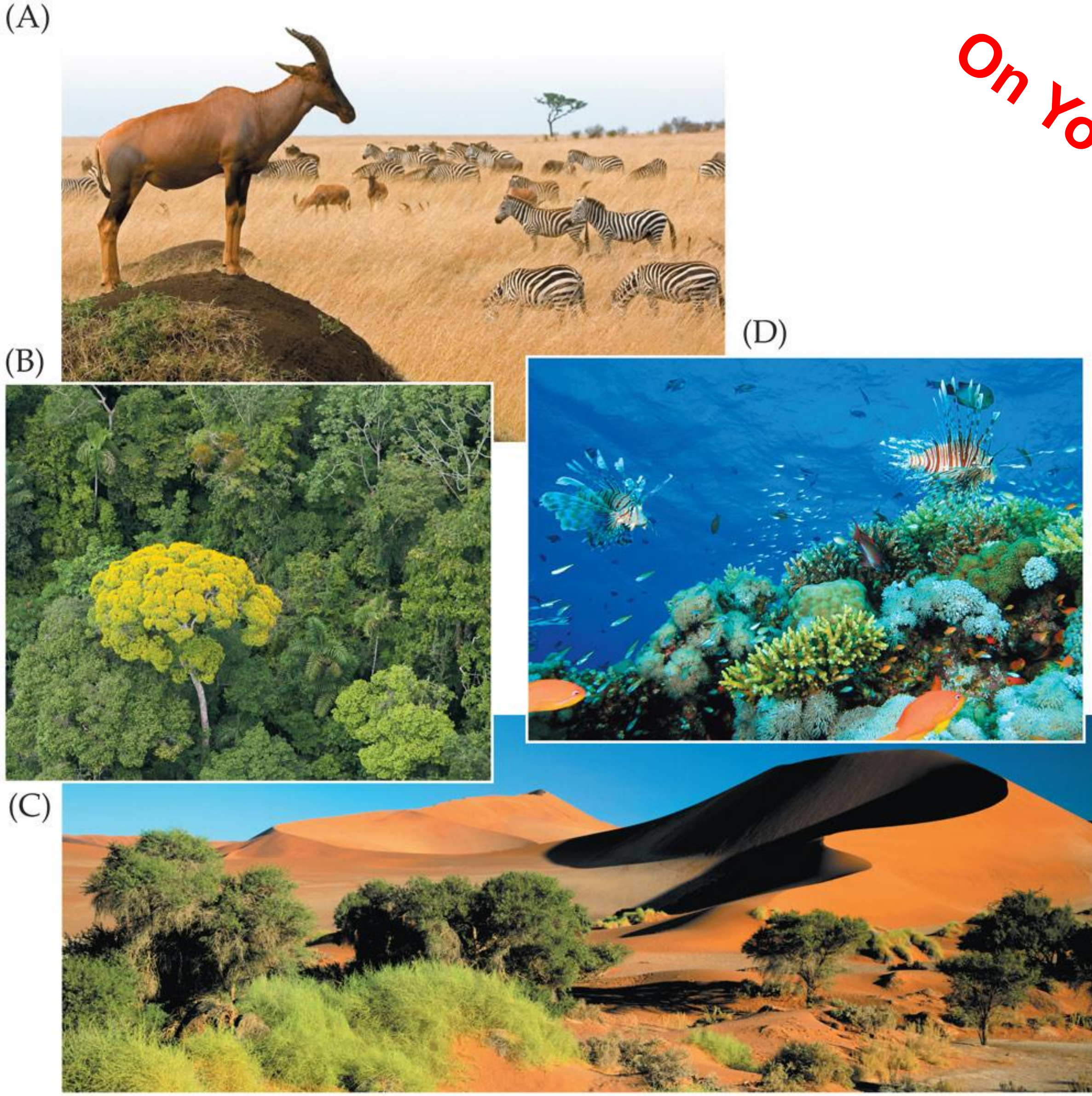
- Association of populations of different species living in the same area.



***ECOLOGY*, Figure 1.8 (Part 2)**

Figure 1.9 A Few of Earth's Many Communities

On Your Own



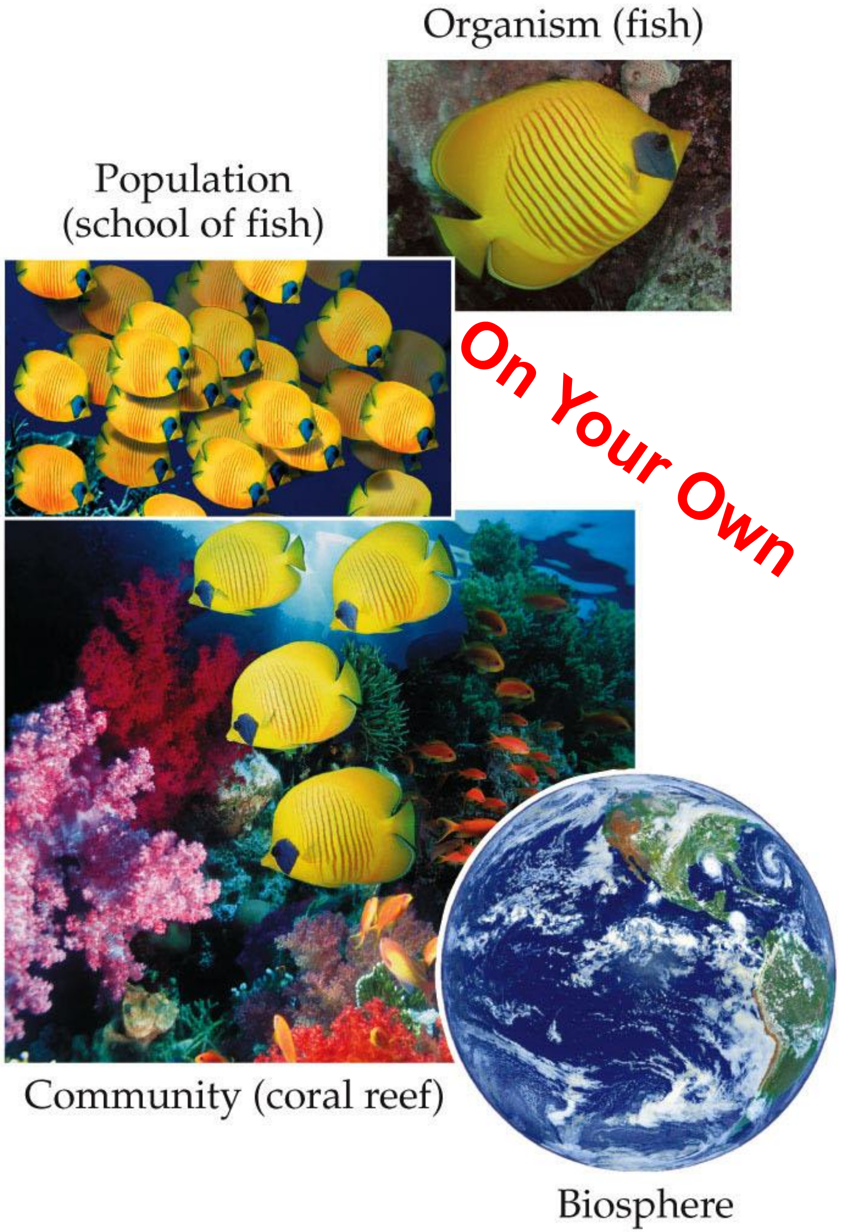
ECOLOGY 3e, Figure 1.9

An **ecosystem** is a community of organisms plus the physical environment in which they live

Landscapes are areas with substantial differences, typically including multiple ecosystems.

The **biosphere:**

- All the world's ecosystems taken together
- All living organisms on Earth plus environments in which they live



ECOLOGY, **Figure 1.8 (Part 2)**

TABLE 1.2

Key Terms for Studying Connections in Nature

Know these terms!!

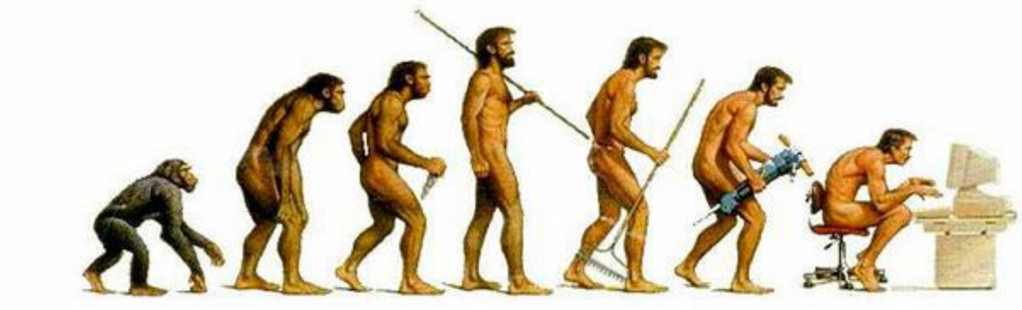
Term	Definition
Adaptation	A feature of an organism that improves its ability to survive or reproduce in its environment
Natural selection	An evolutionary process in which individuals that possess particular characteristics survive or reproduce at a higher rate than other individuals because of those characteristics
Producer	An organism that uses energy from an external source, such as the sun, to produce its own food without having to eat other organisms or their remains
Consumer	An organism that obtains its energy by eating other organisms or their remains
Net primary production (NPP)	The amount of energy (per unit of time) that producers fix by photosynthesis or other means, minus the amount they use in cellular respiration
Nutrient cycle	The cyclic movement of a nutrient between organisms and the physical environment

ECOLOGY 3e, Table 1.2

http://blogs.sun.com/ChinaExperience/resource/evolution.jpg

On Your Own

All living systems **evolve** → change over time



Evolution:

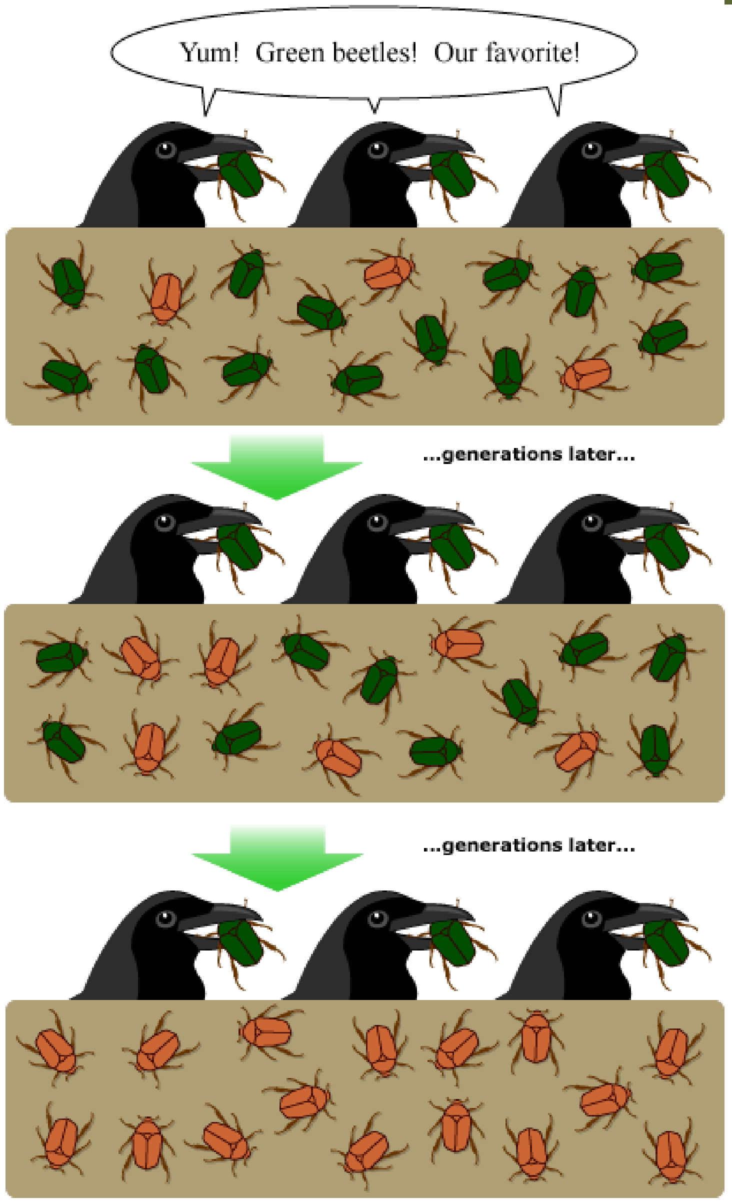
- A change in the genetic characteristics of a population over time
- Descent with modification — organisms gradually accumulate differences from their ancestors
- **Adaptation**: A characteristic that improves survival or reproduction.

On Your Own

Natural selection

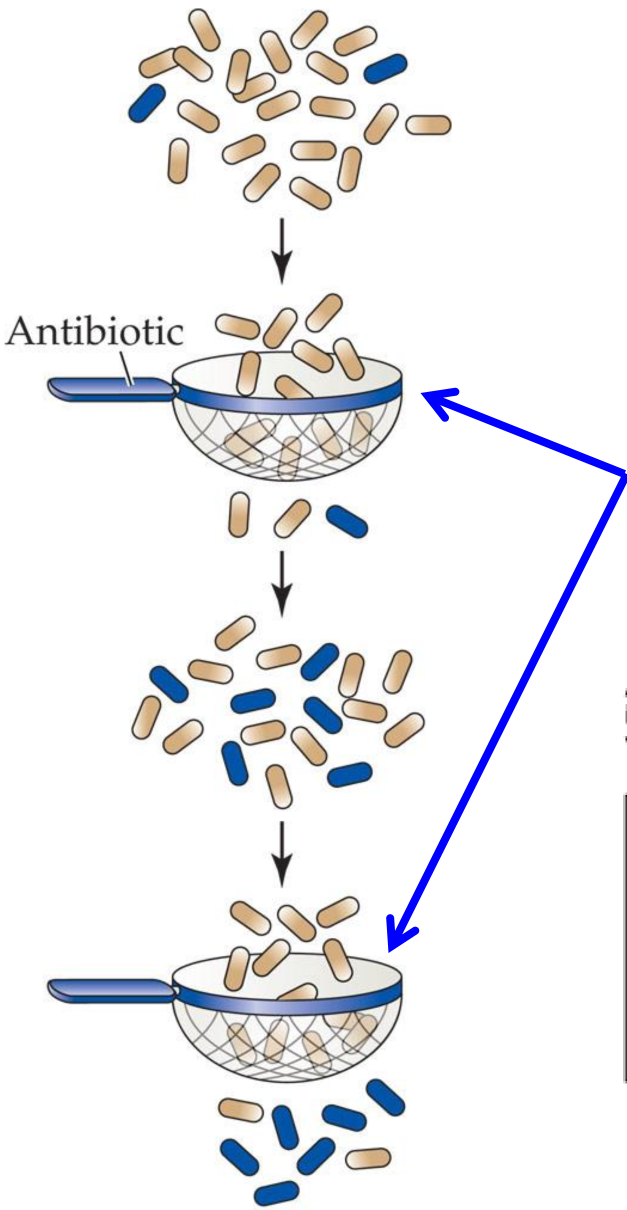
- Individuals within a population with particular **adaptations** tend to survive and reproduce at a higher rate than other individuals
- If the adaptation is heritable, the offspring will tend to have the same characteristics that gave their parents an advantage
- As a result, the frequency of those characteristics may increase in a population over time

Natural selection, in a nutshell:

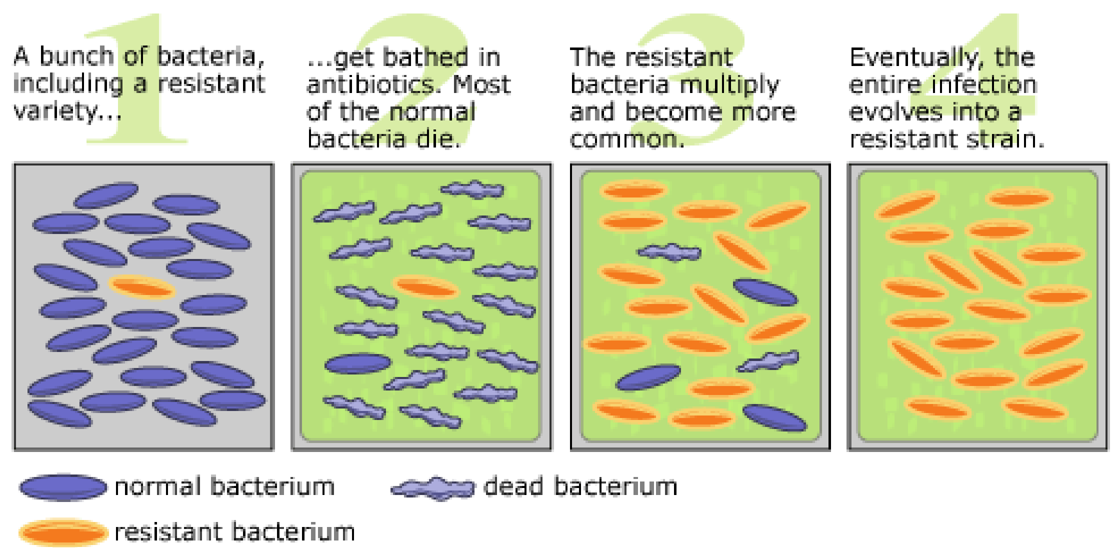


Green beetles have been selected against, and brown beetles have flourished.

Figure 1.10 Natural Selection in Action



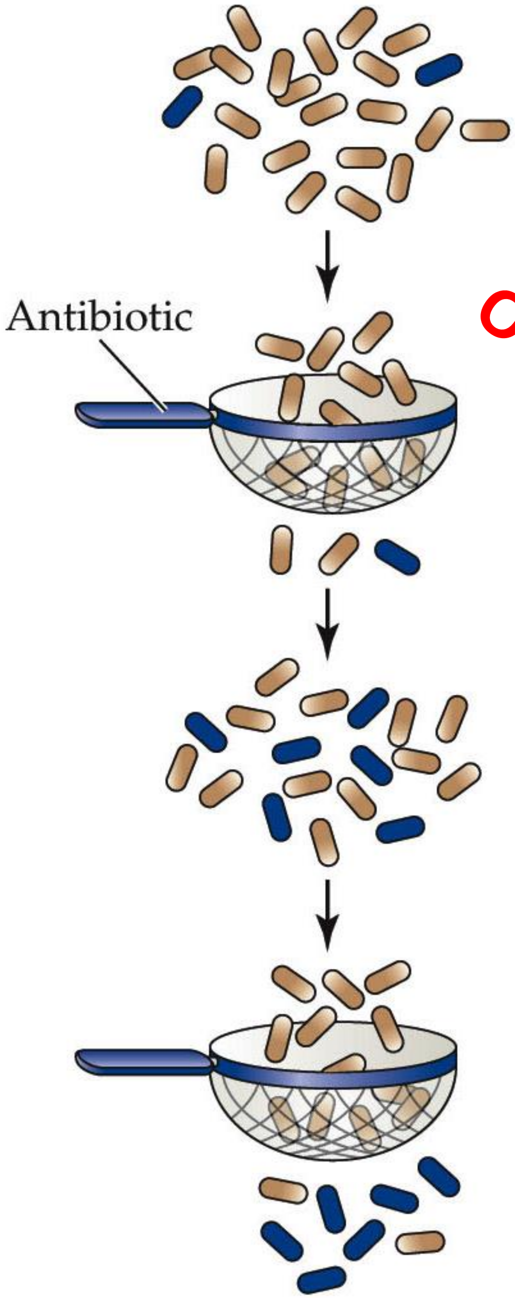
Natural selection is a culling or editing effect, removing individuals without advantageous adaptations



ECOLOGY 3e, Figure 1.10

http://evolution.berkeley.edu/evolibrary/article/bergstrom_03

Figure 1.10 Natural Selection in Action



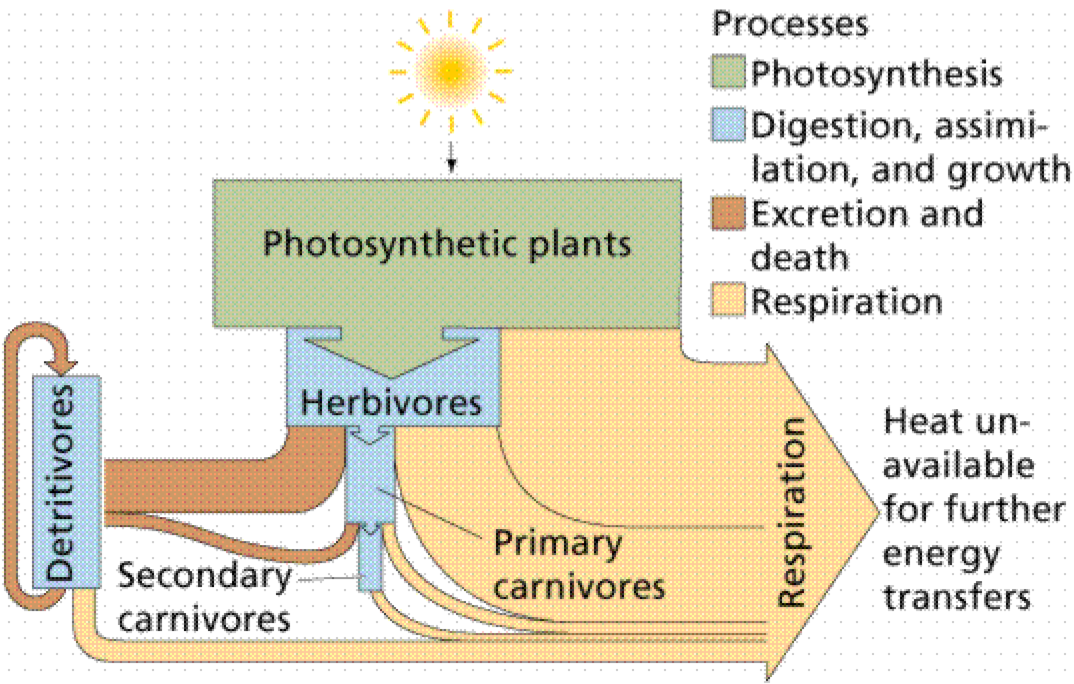
On Your Own

- Three variables important for natural selection to operate
  - **Variation** among individuals within the population
  - **Heritability** of the variations
  - **Differential fitness** (reproductive success) due to variation
- Natural selection is an *editing process*…selection culls out less adapted individuals

On Your Own

Ecosystem processes

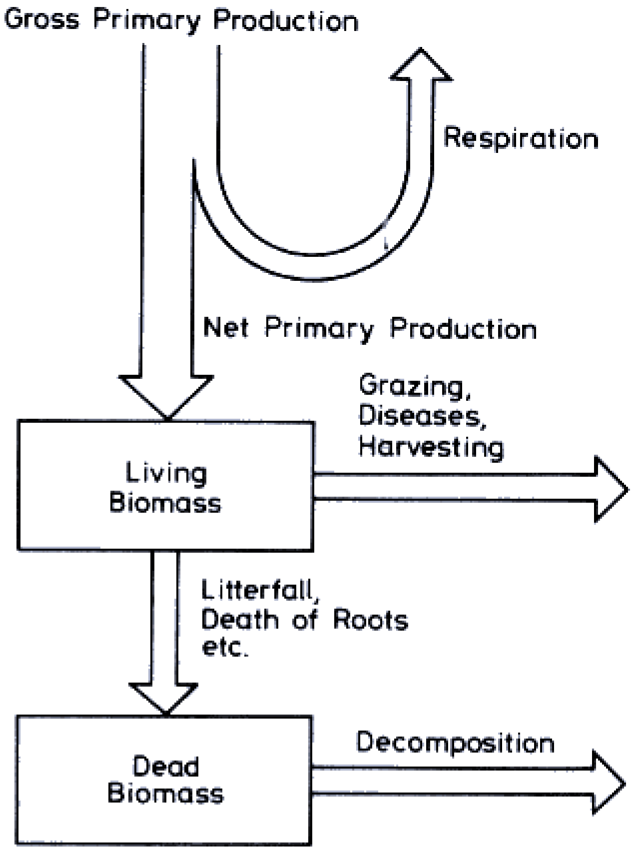
- Movement of energy and materials
- Energy enters community when **producers** capture energy from an external source (usually the sun) and uses that energy to produce food



http://www.estrellamountain.edu/faculty/farabee/biobk/enflow.gif

On Your Own

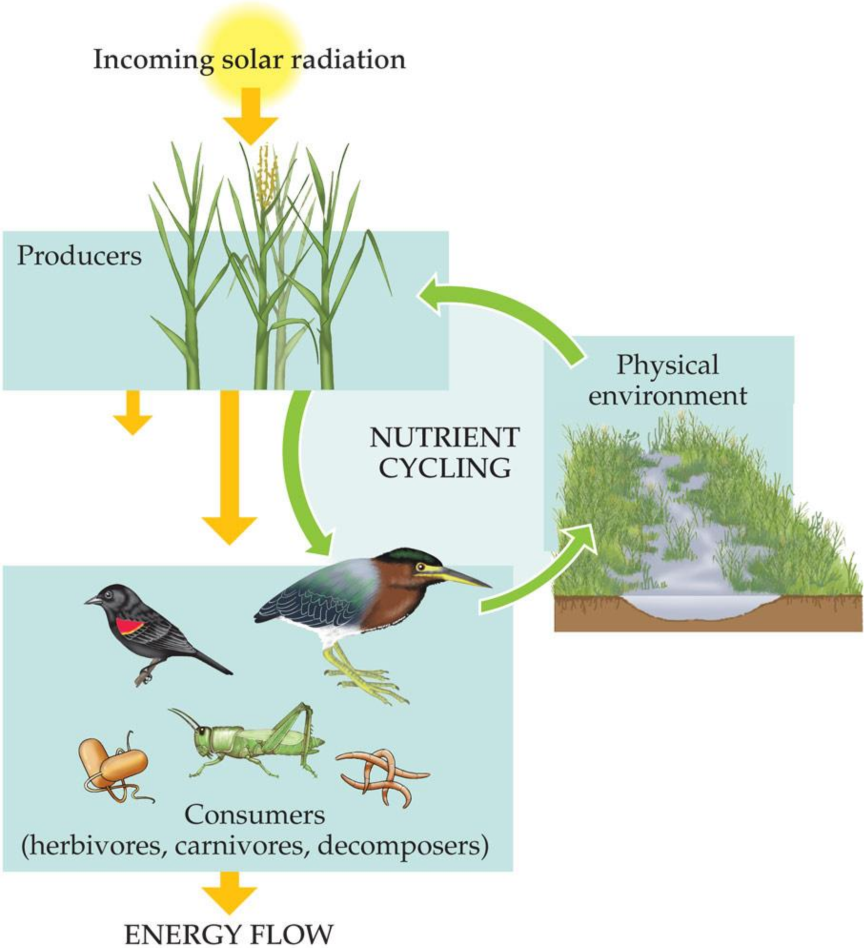
- **Net primary productivity (NPP):**
  - Energy that producers capture by photosynthesis or other means (**GPP**, gross primary productivity), *minus* amount they lose as heat in cellular respiration
  - NPP = GPP - respiration
  - NPP varies among ecosystems and has a large impact on these systems



On Your Own

- **Energy** *moves through ecosystems* in a single direction only — energy cannot be recycled

- **Nutrients** *are continuously recycled* from the physical environment to organisms and back again.



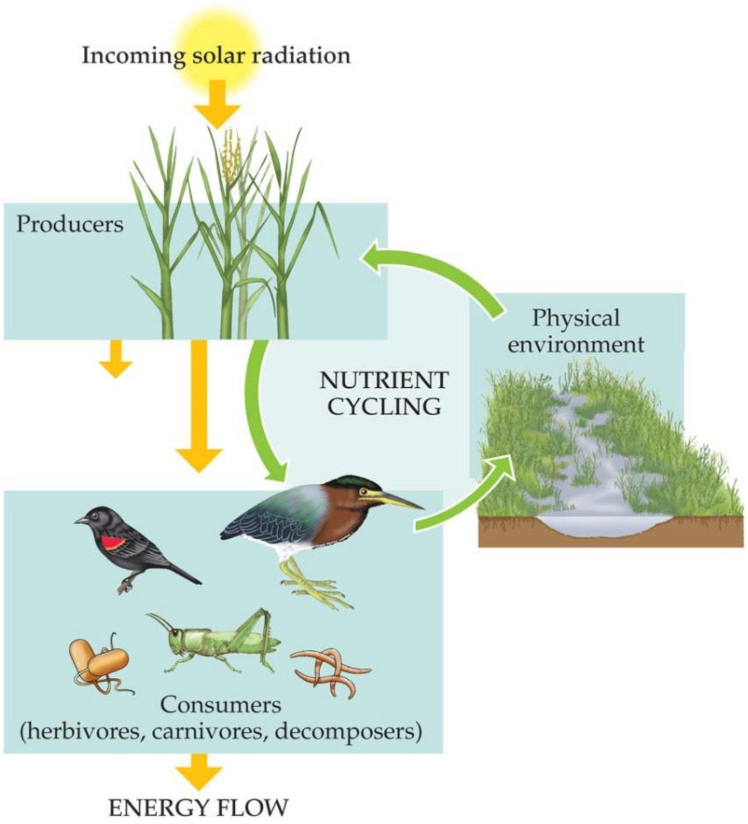
ECOLOGY 3e, Figure 1.11

On Your Own

Nutrient cycle

- Cyclic movement of nutrients such as nitrogen or phosphorus between organisms and the physical environment
- Life would cease if nutrients were not recycled

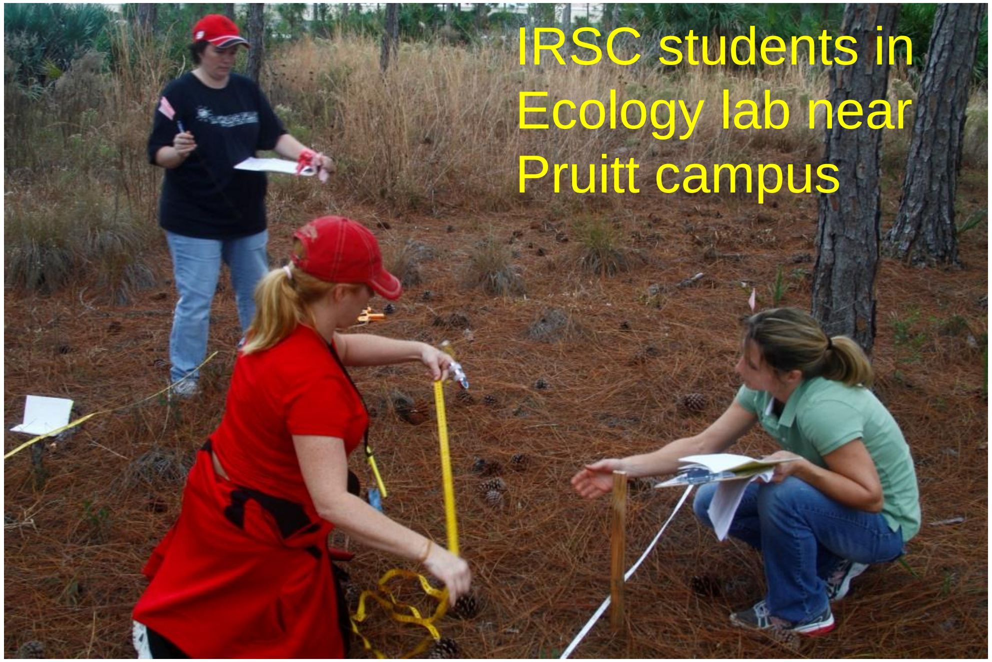
• Likewise, life would cease if energy stopped flowing



ECOLOGY 3e, Figure 1.11

Concept 1.3: Ecologists evaluate competing hypotheses about natural systems with experiments, observations, and models.

Jump to Slide 61



ECOLOGY, Figure 1.5 (Part 1)

Ecologists use several methods to answer questions about the natural world:

- Observational studies in the field (comparative field studies)
- Controlled experiments in the laboratory
- Manipulative experiments in the field
- Quantitative models (computer, mathematical)

Jump to Slide #55

Rest On Your Own

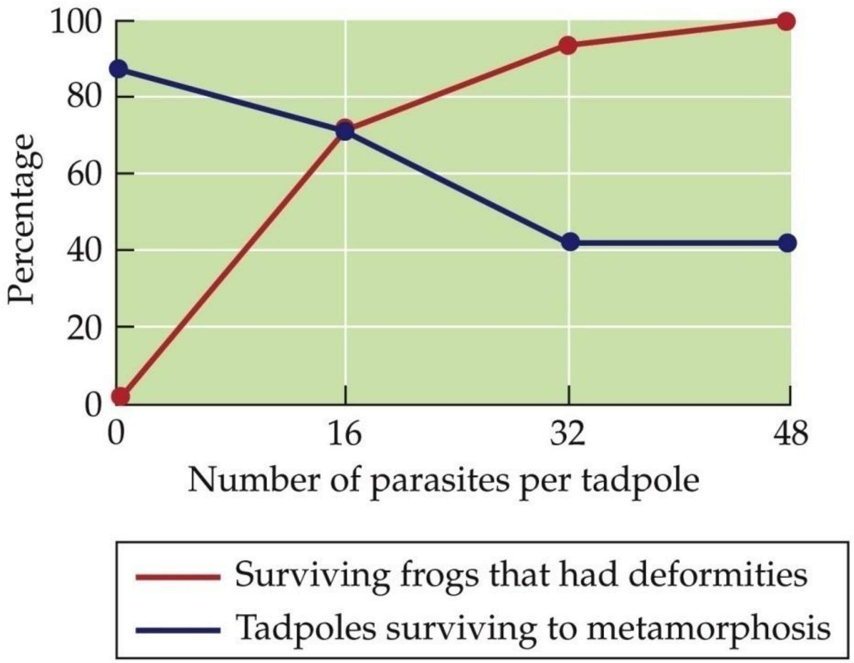
On Your Own

- An observational (comparative) field study:
  - Johnson et al. (1999) surveyed ponds to determine that frogs with deformities were only present if the parasite's intermediate host snail was also present

http://www.converge.org.nz/nbio/images/sampling.jpg

On Your Own

- A controlled experiment:
  - Johnson et al. (1999) also tested their observations by exposing tadpoles to four different levels of the parasite *Ribeiroia* in the laboratory



ECOLOGY, Figure 1.4

On Your Own

- A field experiment
  - Kiesecker (2002) compared frogs from three ponds containing pesticides with frogs from three ponds that had no pesticides.
  - Valid manipulative field experiments must also have controls in the experimental design

ECOLOGY, Figure 1.5 (Part 1)

On Your Own

(A)

(B)

(C)

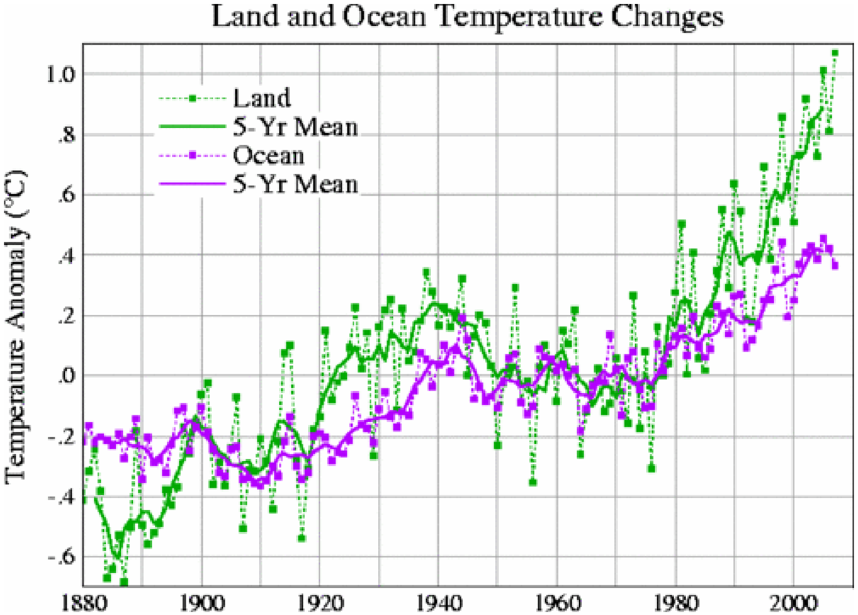
Ecological experiments can be done at different spatial scales:

- Small-scale laboratory experiments in test tubes or flasks, to whole-lake experiments
- When possible, experiments include a **control group**, which is not subjected to any alterations.

On Your Own

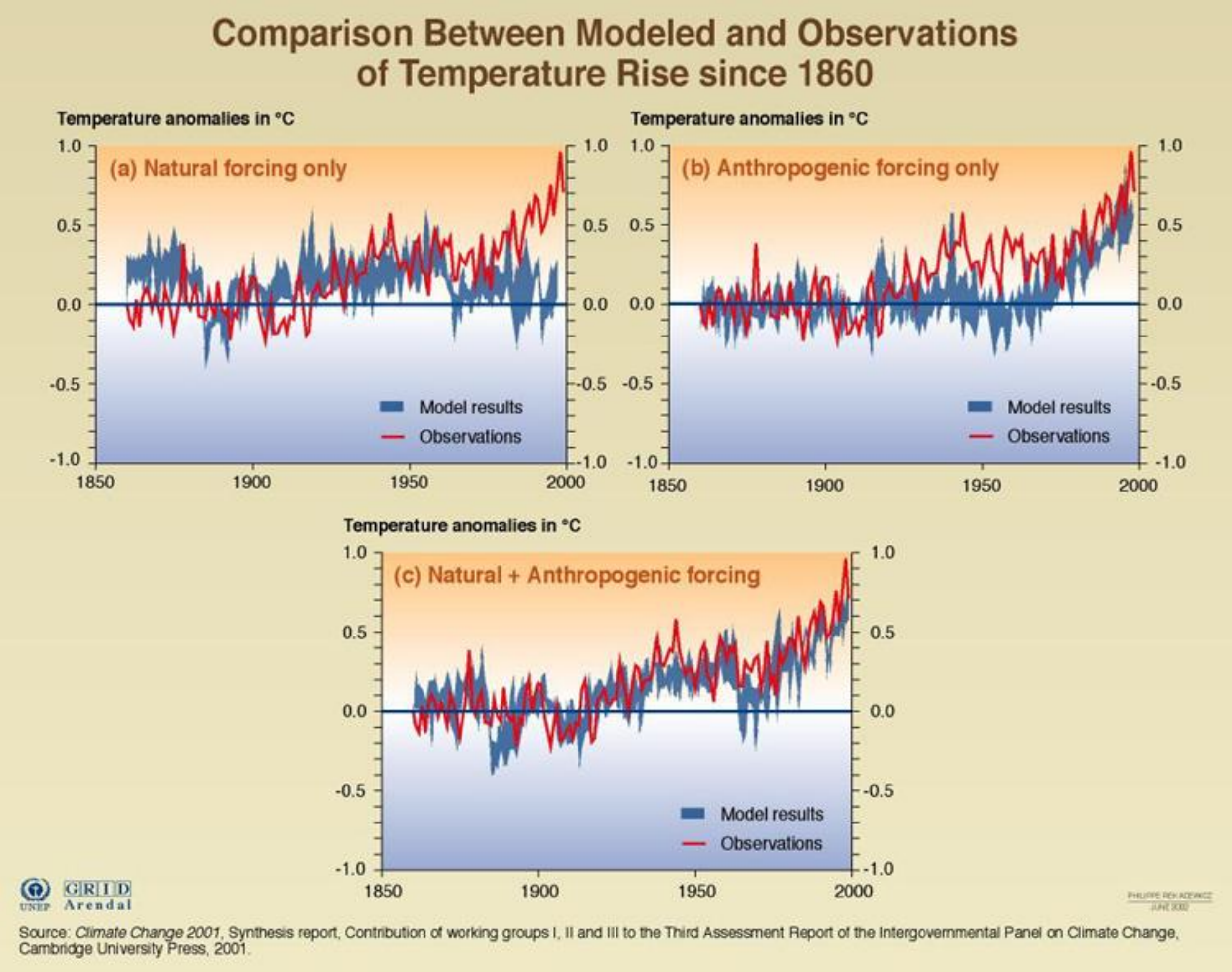
Sometimes experiments are difficult or impossible to perform

- For example…questions concerning events that occur over large geographic and/or time scales, such as global climate change, El Niño
- Possible approach: Conduct observational studies over large regions or for long time periods (limited by lack of control by researcher)



http://global-warming.accuweather.com/gissocean-thumb.gif

- …then data can be entered into mathematical models to help understand the system under study



On Your Own

http://www.grida.no/climate/vitalafrica/english/graphics/11-tarmodel.jpg

Answering Ecological Questions

On Your Own

The study of global climate change involves using a mixture of…

- observational studies,
- small-scale experiments, and…
- quantitative (mathematical or computer) models

Cow farts collected in plastic tank for climate change study

Scientists estimate that methane from cows accounts for more than 30% of Argentina's total greenhouse emissions. Methane is 23 times more effective trapping heat than CO_2

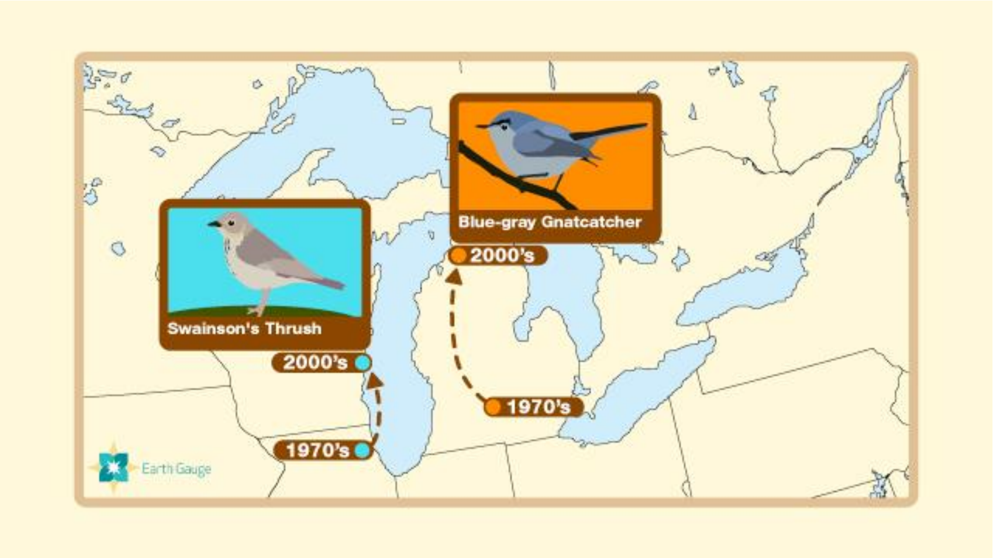
http://www.m4gw.com:2005/m4gw/2008/07/cow_farts_collected_in_plastic.html

On Your Own

Climate change: A directional change in climate (such as global warming) that occurs over 30 years or longer.

- Climate affects many aspects of ecology, and changes have already occurred in the physiology, survival, reproduction, and geographic ranges of hundreds of species.

Many species' distributions are shifting towards the poles already. Swainson's Thrush moved their breeding range latitude 88 miles farther north since the 1970s, while the Blue-gray Gnatcatcher has moved their breeding range 195 miles farther north over the same period.



http://www.earthgauge.net/2011/climate-fact-bird-breeding-range-shifts-great-lakes

Key aspects of **good experimental design**:

- **Replication**
  - Perform each treatment more than once
  - As number of replicates increases, it becomes less likely that the results were actually due to a variable that was not measured or controlled
  - Increased **sample size** within treatments decreases likelihood that effects are due to chance alone

Really important!!!

On Your Own

Layout of field showing **replicates** of 5x5 meter plots in two treatments (with and without insect removal) **randomly** assigned

(A)

ECOLOGY 3e, Ecological Toolkit 1.1, Figure A

Key aspects of **good experimental design**:

On Your Own

- **Randomization**
  - Assign treatments at random
  - Helps limit effects of unmeasured variables
- Standard **statistical analyses** are used to determine significant effects

Really important!!!

Layout of field showing **replicates** of 5x5 meter plots in two treatments (with and without insect removal) **randomly** assigned

(A)

ECOLOGY 3e, Ecological Toolkit 1.1, Figure A

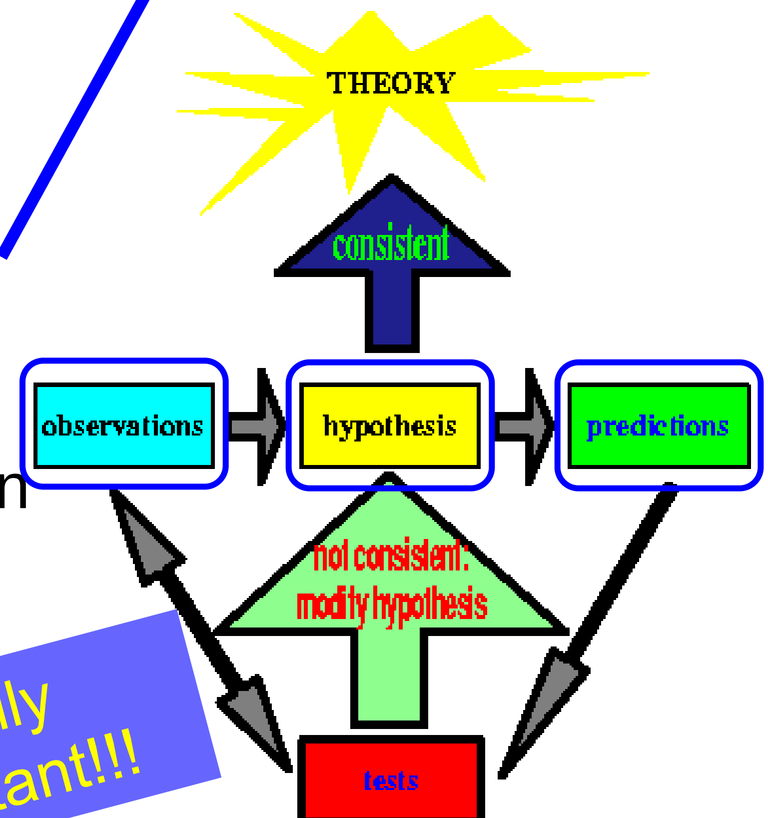
(B)

ECOLOGY 3e, Ecological Toolkit 1.1, Figure B

Scientists learn about the natural world by a series of steps called the **scientific method**:

1. Make observations and ask questions.
2. Use previous knowledge or intuition to develop a **testable hypotheses**, i.e. a possible _explanation_ (**cause**) of phenomenon (how or why)
3. Make a testable **prediction** based on hypothesis… _what will happen_ (**effect**) if hypothesis is true, within context of study design

If…then statement: ***If*** hypothesis is true, ***then*** … predicts something will happen; **Proposed cause…and effect**



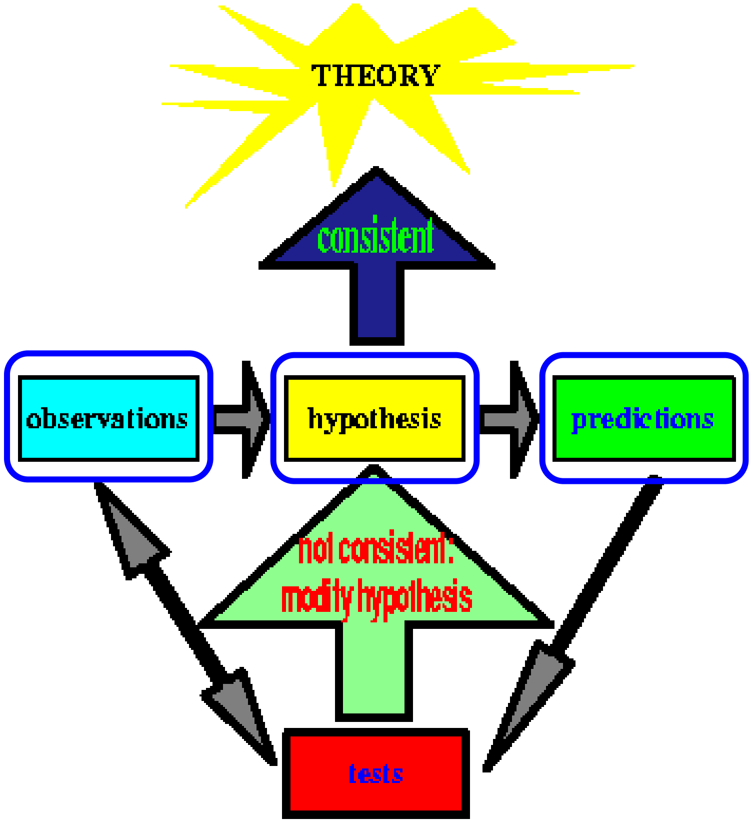
Really important!!!

http://physics.ucr.edu/~wudka/Physics7/Notes_www/img1.gif

Answering Ecological Questions

- Example:
  - **If** Lake "O" nutrient-rich discharges cause plankton blooms in IRL…
    - **then** nutrient levels should be higher in IRL after discharges
    - **then** should detect increased blooms during times after discharges

If…then statement: ***If*** hypothesis is true, ***then*** … predicts something will happen



http://physics.ucr.edu/~wudka/Physics7/Notes_www/img1.gif

Answering Ecological Questions

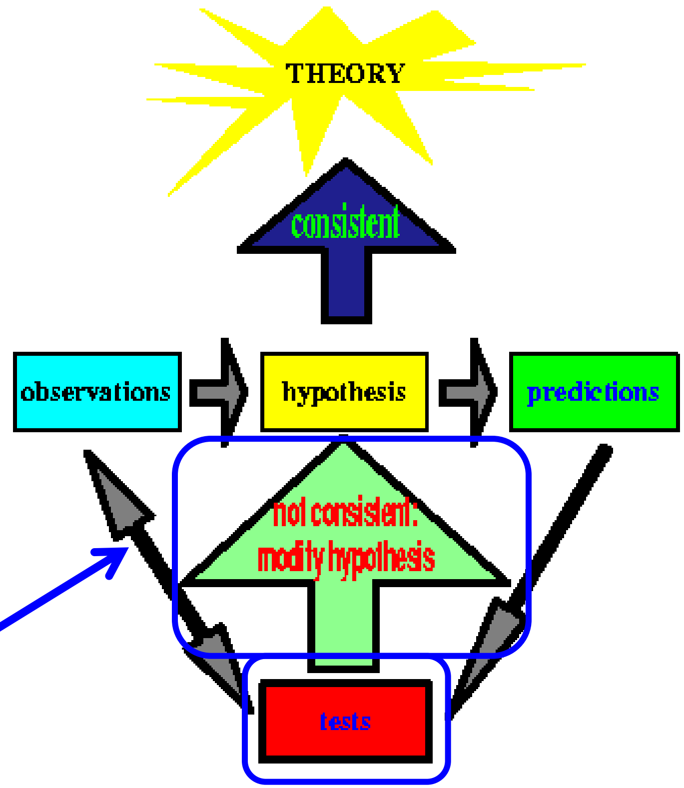
On Your Own

A prediction is NOT what YOU think will happen, it is based on the hypothesis

4. Evaluate hypotheses (*i.e. are predictions true*) by examining results of experiments, a comparative observational studies, or using quantitative models

5. Use results to modify the hypotheses, to pose new questions, or to draw conclusions about the natural world

The process is iterative (repeats) and self-correcting.



http://physics.ucr.edu/~wudka/Physics7/Notes_www/img1.gif

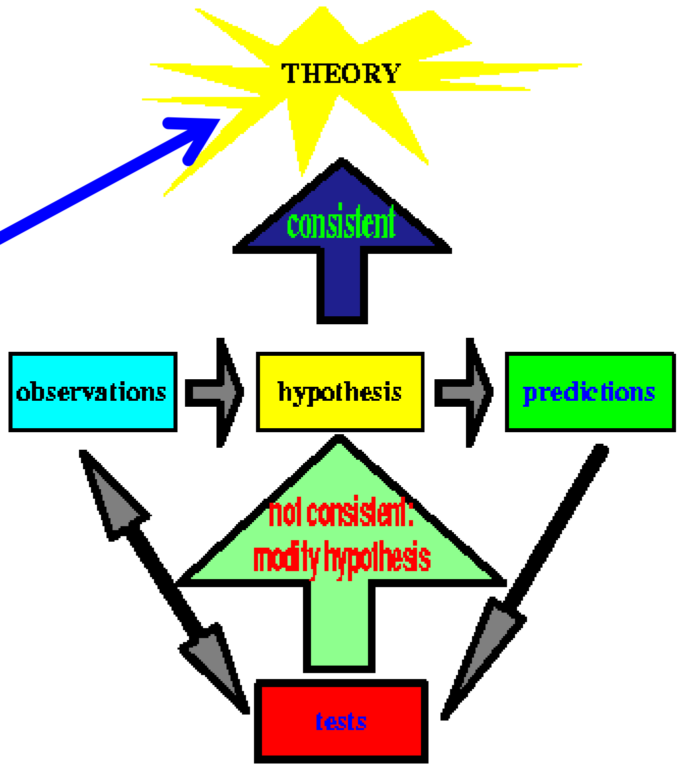
Alternative hypotheses

- Different "explanations" for phenomenon
- E.g. – parasites, pesticides, pollution, UV radiation, habitat loss may account for amphibian declines
- Hypotheses may be ***mutually exclusive*** (single cause) or not (multiple causes)

Ex: ***If*** septic systems are responsible for plankton blooms in IRL, then…

A **scientific theory**

- From consistent results
- Supported by lots of data, usually from many different sources



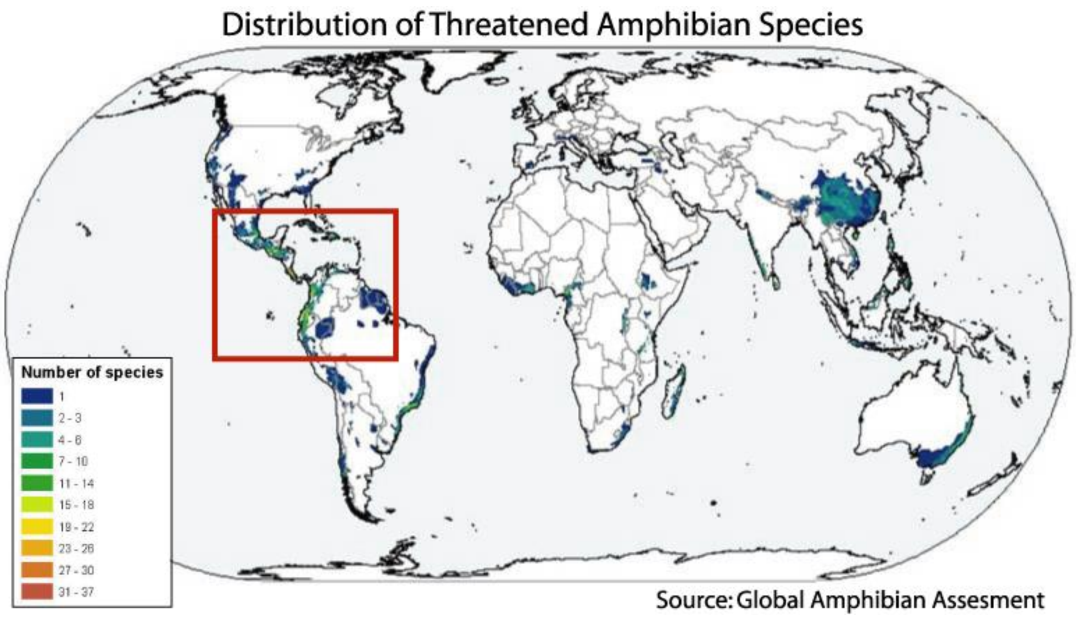
http://physics.ucr.edu/~wudka/Physics7/Notes_www/img1.gif

Case Study Revisited: Deformity and Decline in Amphibian Populations

Studies have suggested that no single factor can explain decline of amphibian populations.

- Declines seem to be caused by complex factors that often act together and may vary from place to place
- The relative importance of factors such as habitat loss, parasites, pollution, UV exposure, and others, are still being investigated.

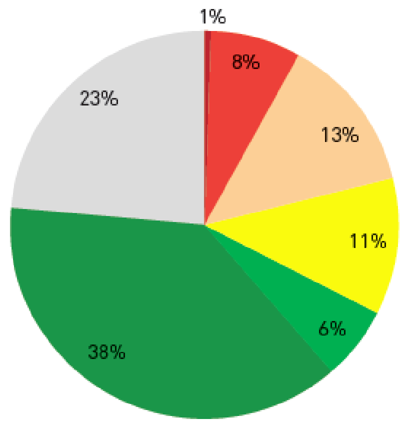
On Your Own



http://amphibiaweb.org/images/gaa_global_threatened_species.jpg

A Case Study Revisited: Deformity and Decline in Amphibian Populations

- Stuart et al. (2004) analyzed studies on 435 species:
  - Habitat loss was the primary cause for 183 species; overexploitation for 50 species.
  - The cause for the remaining 207 species was poorly understood.



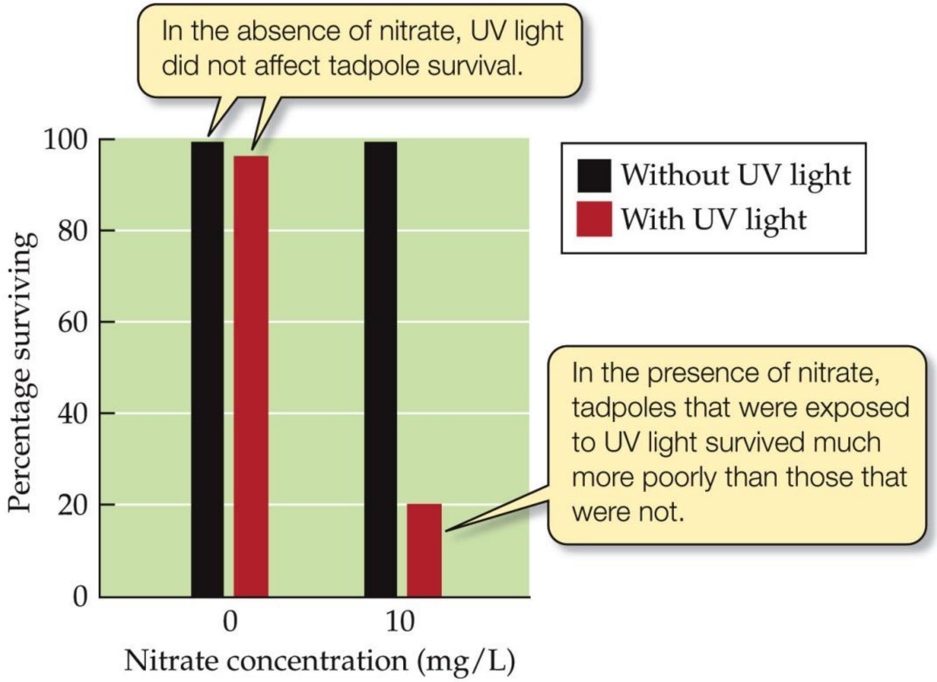
Red List Category	Number of Species
Extinct	34
Extinct in the wild	1
Critically Endangered	455
Endangered	768
Vulnerable	670
Near Treatened	369
Least Concern	2236
Data Deficient	1382
Total Number of Species	**5915**

http://sapiens.revues.org/1406

Hatch and Blaustein (2003) studied effects of UV light and nitrate on Pacific tree frog tadpoles

- At high elevation sites, neither factor alone had any affect
  - *But together*, the two factors reduced tadpole survival

- At other low elevation sites, this effect was not seen



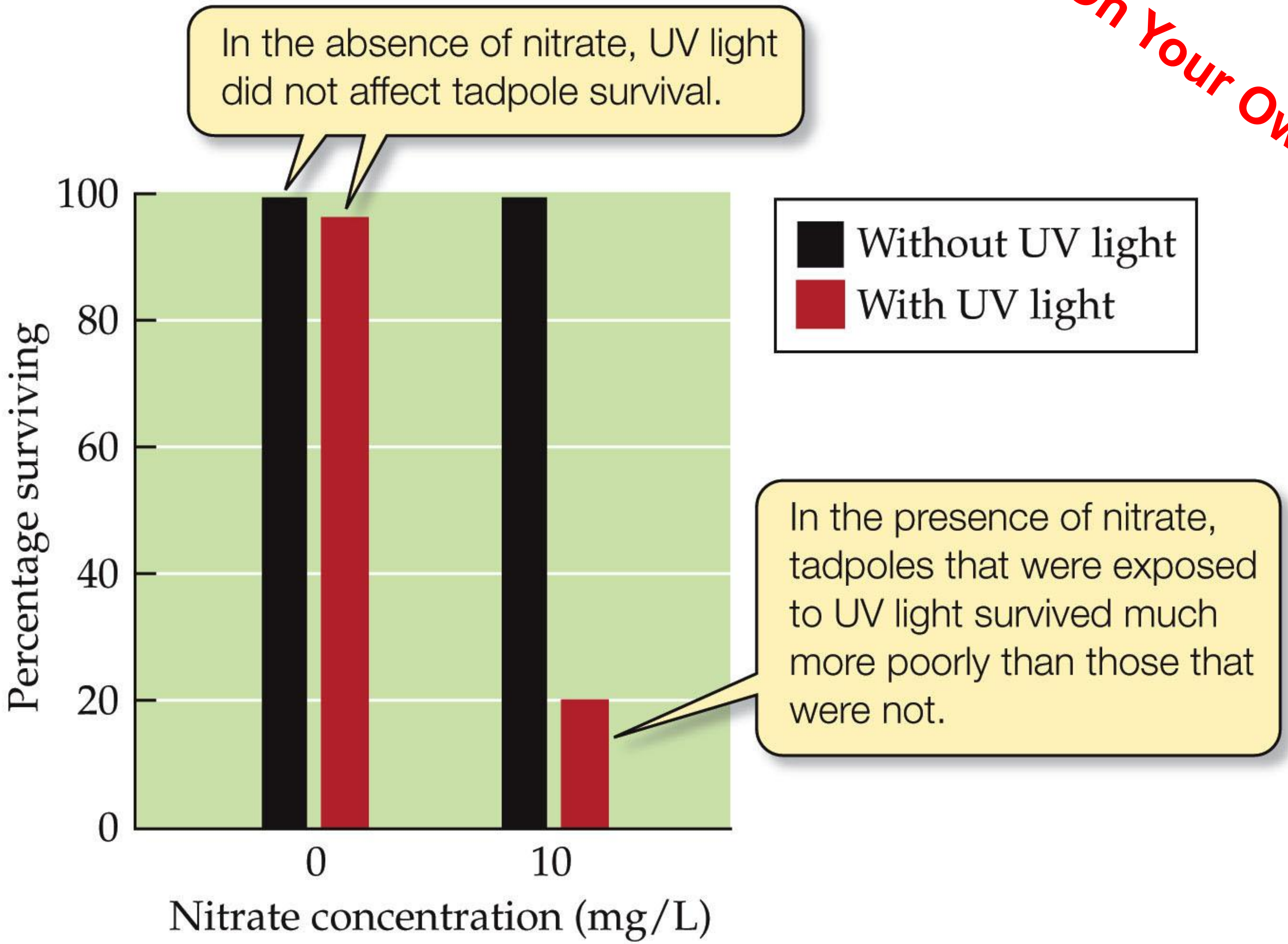
ECOLOGY, Figure 1.14

On Your Own

:://www.fs.fed.us/r4/amphibians/images/pacifictreefrog_tadpole2.jpg

Figure 1.14 Joint Effects of Nitrate and UV Light on Tadpole Survival

On Your Own



ECOLOGY, Figure 1.14

Case Study Revisited: Deformity and Decline in Amphibian Populations

On Your Own

The effects of pesticides are also complex…

- Some studies (Relyea, 2003) show that tadpoles are more susceptible when under stress, such as presence of predators

http://www.donrelyea.com/front_img/big_tadpole_large.jpg

Rick Relyea Studies Deadly Effects of Pesticides (Roundup) on Amphibians

http://www.chronicle.pitt.edu/wp-content/uploads/2007/08/ple-relea.jpg

A Case Study Revisited: Deformity and Decline in Amphibian Populations

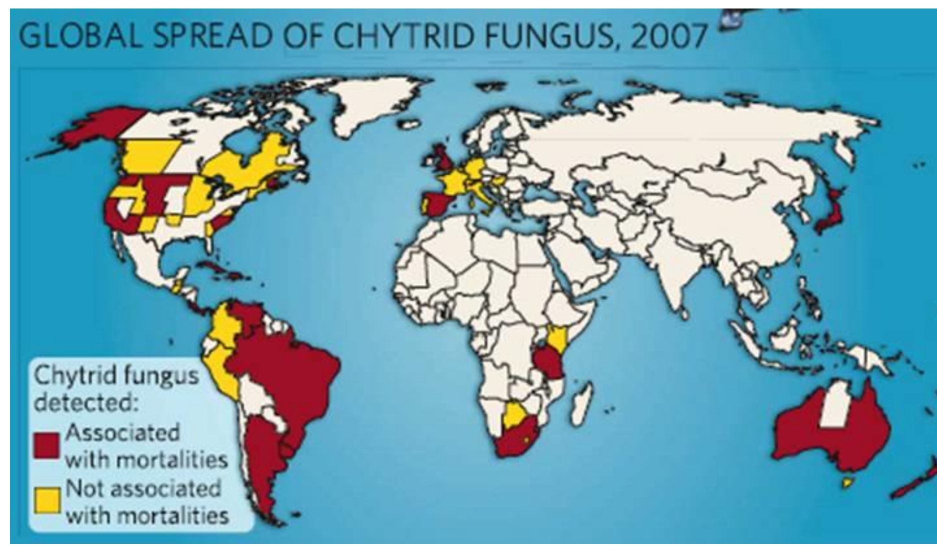
Skerrat et al. (2007) argued that some declines may be due to pathogens

- a chytrid fungus that causes a lethal skin disease and has spread rapidly in recent years.
- climate change and altered conditions may be favoring growth and transmission of disease organisms.

On Your Own

Frog with chytrid fungal infection (*Batrachochytrium dendrobatidis* or Bd infection)

http://news.mongabay.com/2013/0919-watsa-chytrid-fungus-devastates-salamanders.html



https://frogmatters.wordpress.com/category/chytrid-fungus/page/4/

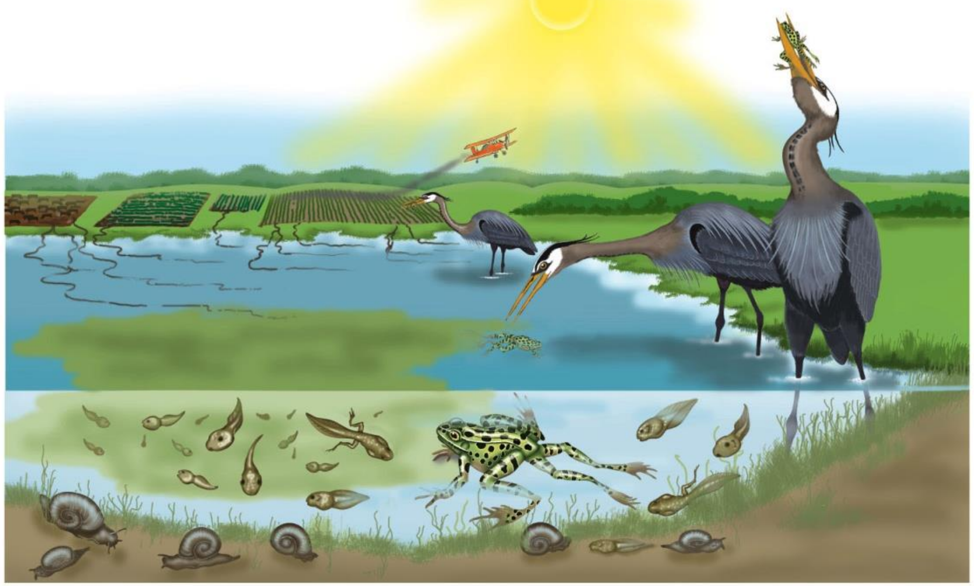
Case Study Revisited: Deformity and Decline in Amphibian Populations

Amphibian declines seem to be caused by complex factors that often act together and may vary from place to place.

- A broad set of factors can cause frog deformities, but little is known about how these factors interact.

There remains much to be discovered in the field of ecology.

On Your Own



ECOLOGY, Figure 1.15

Connections in Nature: Mission Impossible?

On Your Own

The natural world is vast, complex, and interconnected.

- But ecologists think that it is not impossible to understand it.
- Ongoing efforts are sure to be challenging, exciting, and important to the well-being of human societies.

http://www.payvand.com/news/08/jun/Earth-BlueMarble-NAASA.jpg