# Ecology - Introduction

## What is Ecology, Course Structure and the Theory of Evolution by Natural Selection

# What is Ecology?

- Let us develop a working definition of Ecology and what it means to us…
- What are the component parts?
- What are the relationships among the components? Is this unidirectional? We will return to this later!
- With this considered, what is our definition of the Ecology?

## 1.3 The natural world is dynamic, but it is also stable and self-replenishing.

We have seen how our questions and observations may lead us to an appreciation of pattern and complexity in the natural world. If we inquire even more closely and observe even more keenly, we shall also discover that there is a constant tension between change and equilibrium in nature. The forest near your neighborhood may appear to change little from year to year. But the forest community actually undergoes constant turnover, with the removal of individuals by death and their replacement by birth. Just as the general shape and size of your body remains relatively constant while the cells and molecules within it are continuously replaced during your lifetime, the forest remains a forest, even though its components are constantly changing.

Populations of organisms are also continuously replaced. An insect may lay thousands of eggs each year, and some marine organisms shed millions of eggs into the water—more than necessary to compensate for losses of individuals from their populations. Yet in spite of the tremendous potential for growth, various checks and balances keep the size of most populations within rather narrow limits.

All systems suffer disturbances (from weather, fire, treefalls—even a cow pat creates a major disturbance for some organisms) from which they are continually recovering (Figure 1-12). Patches of disturbance may range from a few millimeters, as when an earthworm eats its way through the soil, to large portions of the earth, as when global weather patterns shift. Much variation is imposed by the physical environment—climate, ocean currents, landscape—but much is also generated by the biological world. Many organisms create disturbances for others as they forage and move about. The dynamics of population interactions can establish cycles of population change that send ripples throughout the biological community. Variation must be considered a part of the equilibrium of the natural world.

Renewal and replenishment are also characteristics of the natural world. The dead bodies of organisms and the wastes of biological processes do not pile up. They are broken down, and their component parts are recycled by the community. The dead leaves rustling under our feet cover the decomposing remains of other leaves in the soil beneath them. Soil organisms transform their elegant shapes into an amorphous mass of decaying and decomposing plant tissue called humus, finally reducing them to the mineral elements from which they were once, in part, synthesized.

# In a Historical sense…

- As long as there has been a species *Homo sapiens,* or for that matter, members of the genus *Homo* (and before), we have been interested in the relationships among species and their environment – initially because those species in the environment were our dinner
- Our concern today of the relationships of species and the environment is no less important, but generally for other reasons

# Consider the importance of extinction rates

- Realistic estimates for background extinction rates range from 1 to 5 species lost per million species per year (how many spp?)
- Some sources estimate the rate of loss today, however, to be 50 to 100 K species on an annual basis
- Tropical forests are an area of special concern and many of the ecologists working in these areas have estimated the number of extinctions to be in terms of numbers per hour or even per minute!

# **Now**, *what is importance of Ecology*?

- As alarming as these statistics are, there are huge discrepancies in these estimates.  One per minute puts the rate at over 500 K lost per year, but the estimate of one per hour is more than an order of magnitude less
- So, why the differences among estimates?

# Our class activities

- We will engage in a variety of components and levels of investigation in this class
- We will perform lab exercises as part of our labs and engage in a group project that is relevant to the discipline of ecology
- You will also do an independent investigation – basically a research paper

# Let us look at the course structure

- **Note the exam dates and times** – these cannot be changed. There is one midterm and a final exam
- Reading assignments from your text are listed on the course syllabus (please read before or just after lecture to help understand the material)

# Lectures

- I will use a combination of methods, including PowerPoint, board lectures and videos if we have the time
- I will post my lectures such that you can preview the lecture prior to class, bring copies of the slides to class, or simply review after class
- As the course progresses, please let me know what works for you because that helps me better gear my presentations to your needs

# Discussions

- The discussion and field activities are not optional
- Two of the activities will have assignments with work that will need to be turned in that day
- You will have an opportunity to work on your group presentations during the second week and present the findings the fourth week

# Before we go too far,…

- We need to consider a more basic question – **What is science?**
- What do we think of when we employ scientific methods to address questions?
- What are some of the attributes of scientific analyses that make it different than other methods of investigation?
- Can we identify the features of science that separate it from other modes of inquiry?

# Attributes of Scientific Studies

- Objectivity
- Rigorous
- Experimental
- Controlled
- Formalized
- Most importantly, the Hypothetico-Deductive Method of analysis

# In the beginning…

- All studies or analyses begin with a **question** – derived from observations that can either be informal or casual **or** observations that are based upon careful measurement of phenomena
- We can draw conclusions from these observations via the process of ***inductive reasoning***
- But, at this point, we are still just being descriptive with regard to our studies

# Now, what if we want to explain

- That is, we want to develop an explanation of our observations, not just a specific explanation for our case, but a general explanation of similar phenomena – this employs the hypothetico-deductive method
- And, the first component is to propose a **hypothesis**

# Features of a hypothesis

- Hypotheses are explanations of the general question, not just an explanation of the observations, but the ***cause*** of the observed data
- ***The*** feature of a hypothesis is that this explanation must be **testable**. That is, the explanation must be falsifiable by experimentation (and often, several alternative hypotheses are proposed)

# Our hypothesis…

- The hypothesis, as a general explanation, should allow us to make ***predictions*** with regard to similar situations – this is the "if, then" logic (we should actually get used to the if, then, because logic)
- This **is** the deductive reasoning component of the method – we should be able to extrapolate to similar phenomena and compare these observations to the predictions of our hypothesis

# Experimentation

- Some of these predictions can be tested by simple observation, but in other situations, experimental manipulations are required
- Experimental design should allow, as much as possible, control of potential contributing factors that could influence our observed results – these are the variables

# Now, what if?

- What if our predictions match the experimental results? What if it is an exact match?
- What if the results differ from our expectations?
- How do we decide "how different is *too* different"?

# Science is a process

- The results of experiments most often do not turn out the way we expect. Does that mean failure?
- If in fact the results differ from predictions, I suppose the first place to start is to check our experimental methods – but if the methods are sound, is there value in rejection of a hypothesis?  Do we ever completely throw out a hypothesis?

# Biology as a Discipline

- Biology as a science has an added dimension that the physical sciences lack – that is the characteristic of life
- But what does ***life*** mean?  That is, what do living things do, that separate them from the non-living objects in our surroundings?
- Any thoughts?

# Living objects exhibit *order*

- Organism's structures are arranged in a hierarchical fashion both in terms of structural characteristics and processes associated with the activities of organisms
- Is this different than non-living objects?
- How is this different, and at what level do these relationships exhibit the differences?

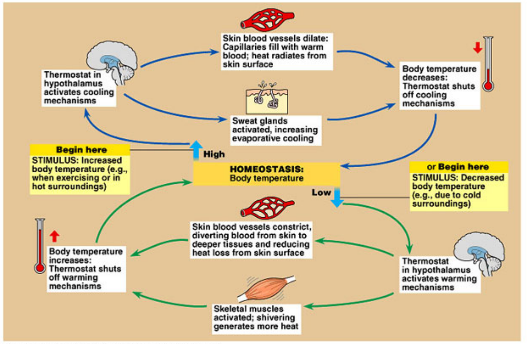
# What are the levels?

- We must begin with **subatomic particles**
- Then, the **atoms**
- Then the **molecules**
- And then the **organelles**.  Now what?
- The **cell**, the basic living unit
- Then **tissues**, **organs** and **organ systems**
- To the multicellular **organism**
- We can continue to the **population**, **community**, **ecosystem** and finally the **biosphere**

# Respond to stimuli

- Organisms respond to stimuli in the environment – and not just external stimuli, but internal stimuli as well
- These stimuli can be a physical characteristic or …
- The source of the stimuli can be biotic – that is, other organisms

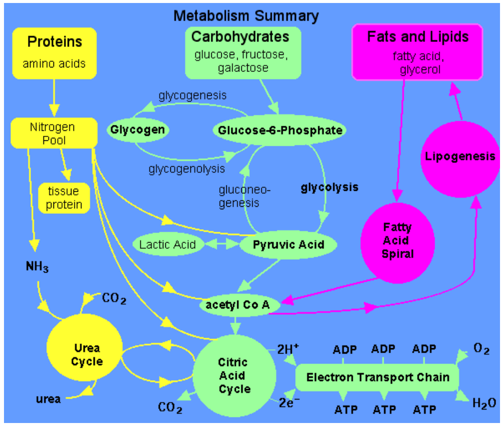
# Homeostasis



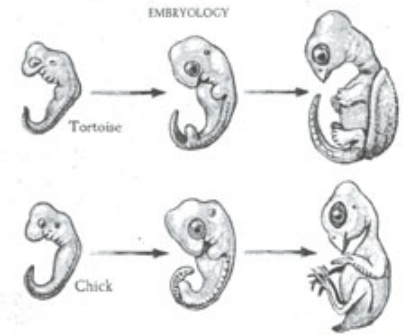


- Another feature of organisms is the characteristic of **regulation**
- Homeostasis means "same state" and this can be dynamic or static
- Typically, when we look at this with respect to organisms, we generally associate this with an internal environment – that is maintenance of a *constant* internal environment (but we will see more later)

# Metabolism




- Organisms extract energy from their environment and transform that energy – this is metabolism
- Note these processes can be catabolic in nature, or
- These may also be anabolic type reactions, or synthetic reactions

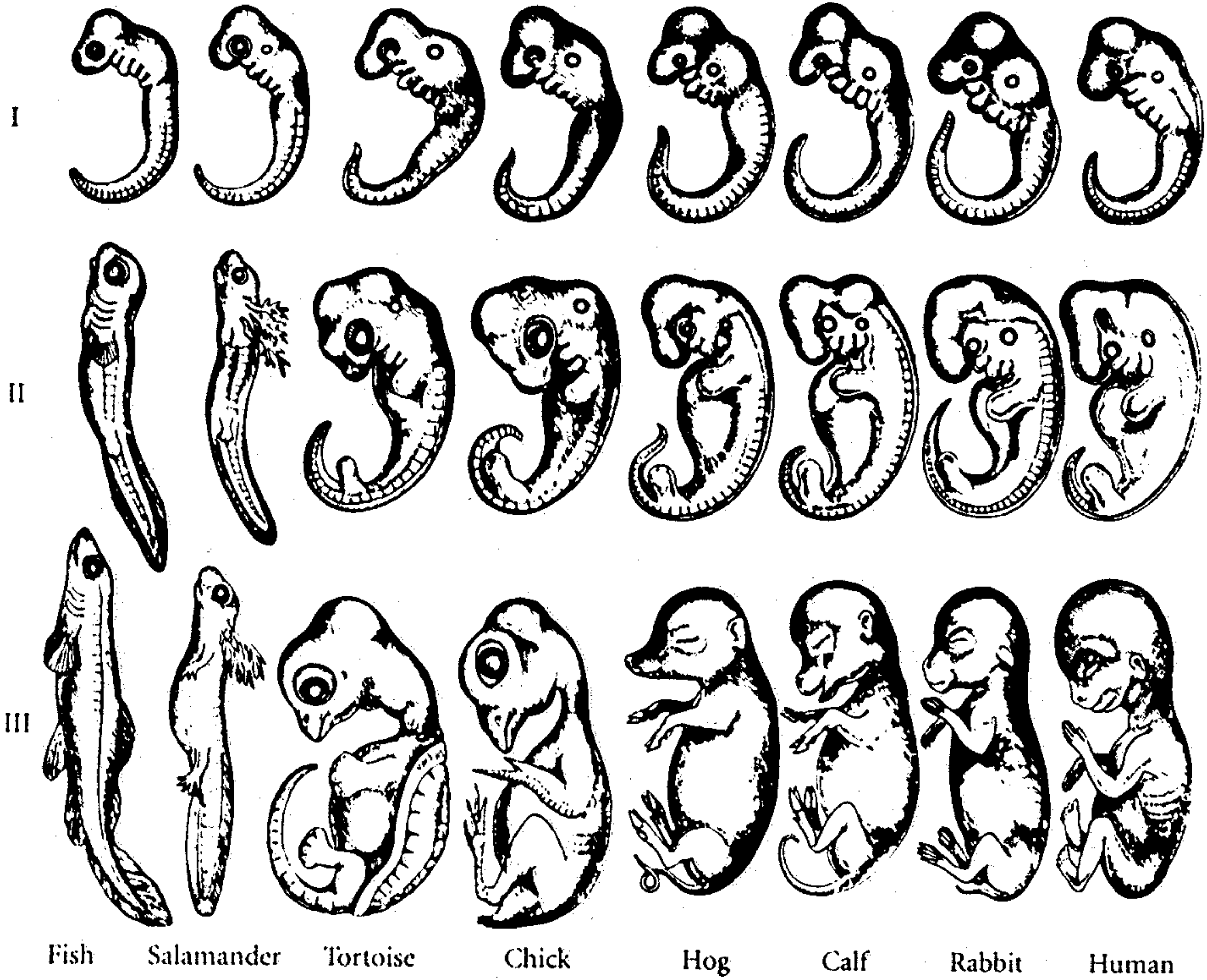



# Organisms Develop

- All organisms follow a specific ontogenetic pathway – *the embryonic and post-embryonic history of an organism*
- Ontogeny encompasses the totality of an organisms life, from conception (or budding) to birth, growth to the adult form
- The adults are defined by the ability to reproduce and the cycle begins again

# “Ontogeny Recapitulates Phylogeny”

- That is, the ontogenetic development of a species encapsulates the phylogenetic (evolutionary history) of that species
- This was Ernst Haeckel’s “Biogenetic Law”
- The literal translation is absurd, but was applied in the study of relationships
- The embryonic development *does include some of the juvenile or embryonic stages* of its evolutionary history – but clearly not the adults


I
II
III
Fish
Salamander
Tortoise
Chick
Hog
Calf
Rabbit
Human

# Reproduce

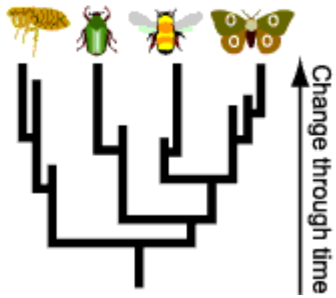
- Organisms have the capacity to reproduce themselves, that is, produce similar forms to themselves
- We look similar to our parents and to our siblings – we owe that to the hereditary material DNA (deoxyribonucleic acid)
- Thus, there is continuity in form – **like produces like** (but not always!)

# Cells…



- The cell theory states that all organisms are composed of at least one cell and the cell is the basic living unit
- Closely associated with this is the **theory of Biogenesis**. *This theory states that life only comes from pre-existing life*
- This is contrary to the hypothesis of spontaneous generation (but it must have happened at least once, right?)

# Finally, organisms evolve




- That is, populations change through time
- Populations of organisms respond to changes in the environment and pressures due to other organisms
- The same molecules that help maintain the consistency from generation to generation may also change and act as the basis for all new information for a given species creating variability in the population
- We will discuss this more in just a few…

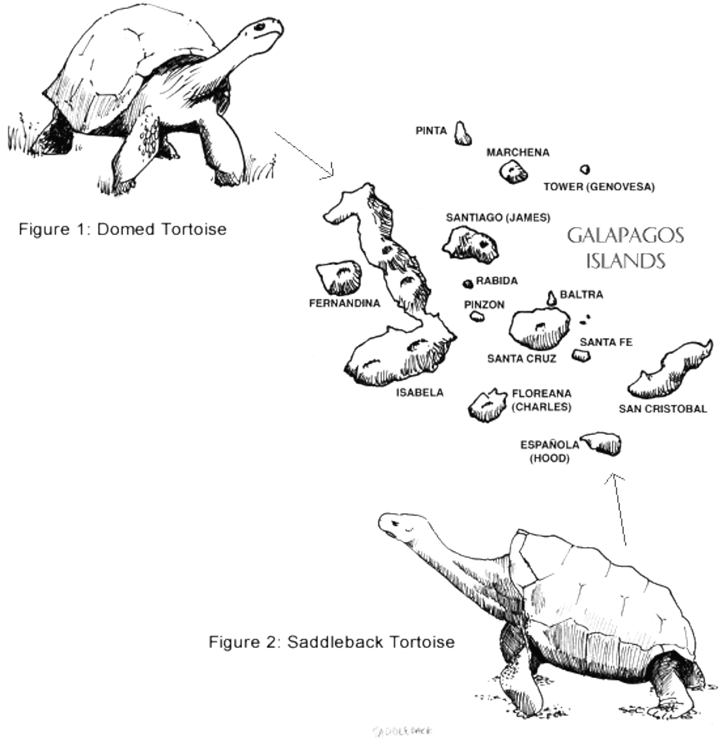
# Enrollment

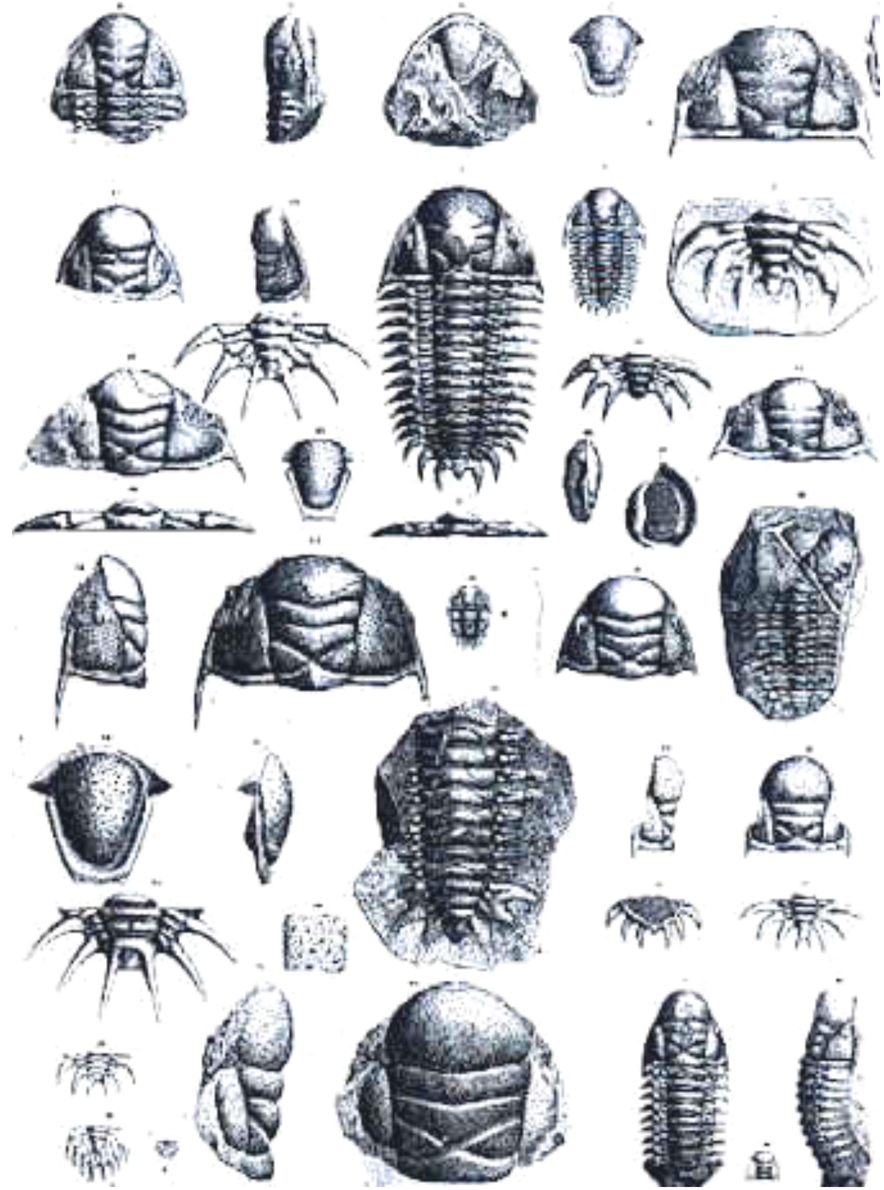
- Please fill in your name in the seat that you are in today.  It is not a seating chart and I will not note if you are here each day, but I do suggest that you attend if at all possible
- At the break, feel free to ask any questions you may have with regard to the class and structure/logistics

# Let us take a break

# Focus of our activities?

- Ecological analyses look at relationships on several levels – intraspecific, interspecific, and between the organism and its environment. Often we treat this from the *adaptationist* perspective and that is okay, because we need some sort of framework that we operate can within (which is?)



# Evolution by Natural Selection

## The Theory and Evidence for Evolution in Natural Populations

# Ecology Analyses

- When investigators study organisms, generally the questions emerge as either “how” or “why”. Look at the roots for these types of questions
- “How” questions are often analyses of proximate causes – that is, the here and now sorts of objects or stimuli in the environment that are the immediate *cause* of certain activities or interactions

# The “why” sorts of questions

- These are questions that tend to go beyond the existing conditions and look more at the *ultimate* causes for particular phenomena
- These analyses look at the evolution of patterns observed in organisms – really the focus of ecology in the sense that we tend to study the adaptive nature of these characteristics

# Potential ultimate and proximate factors influencing feeding

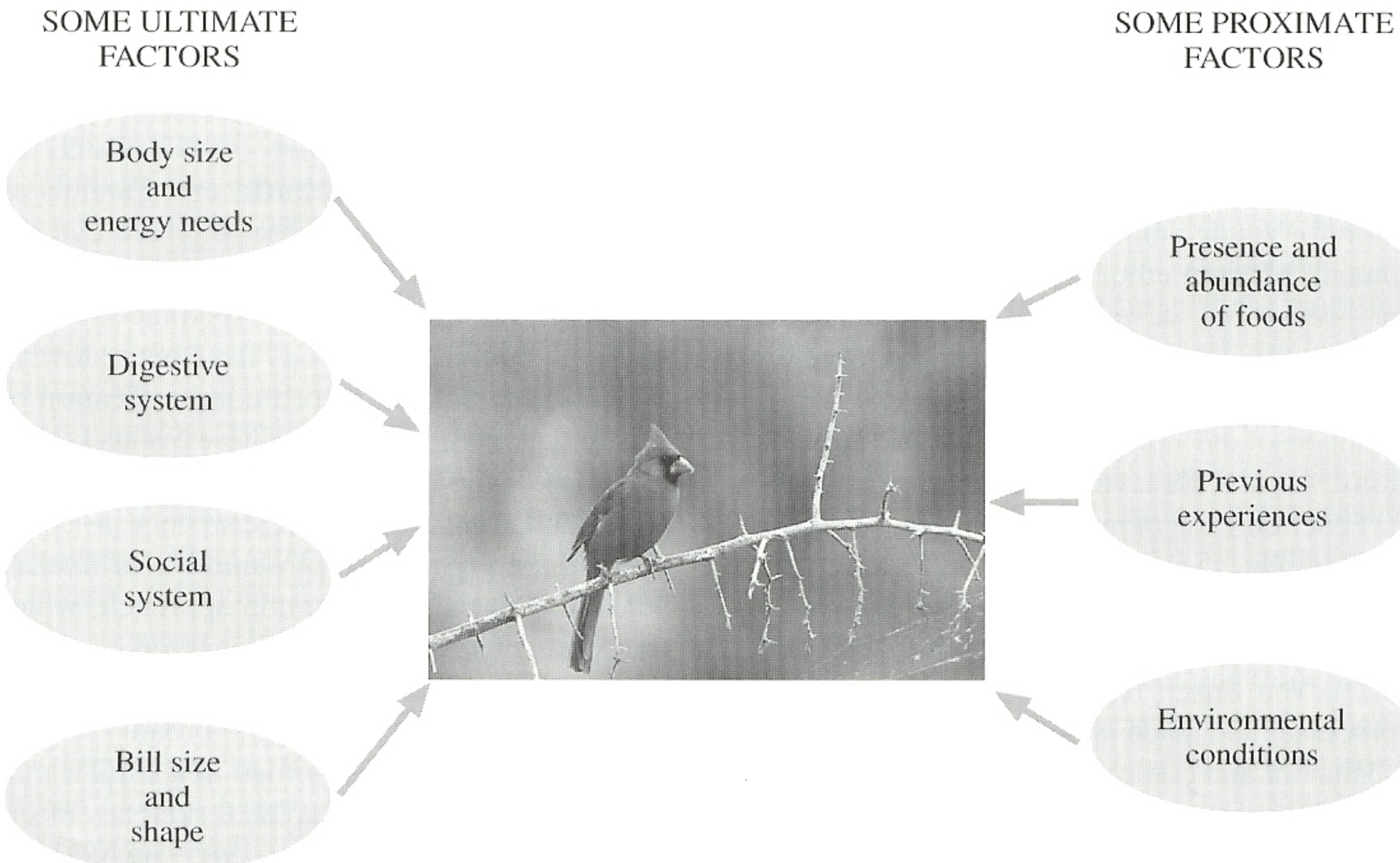



**FIGURE 2.6 Factors affecting the feeding behavior of northern cardinals.** Constraints that have arisen through evolution establish the limits on the dietary habits for the cardinal. Past experience and current environmental conditions influence the immediate choices made by the animal as it forages.

# Implications of Evolution

- Understanding the processes is at the heart of inquiry, and nowhere is this more relevant than the understanding of the selective pressures faced by animals in their natural environment
- Let us very briefly review the processes that have, at least in part, shaped the organisms around us and later we will consider some of the abiotic factors associated with the adaptation of organisms to their environment

# Let us start with ***change***

- How can we define evolution?
  - In the most simple terms, change through time
  - How about **"the process by which populations of organisms change from generation to generation"**
  - On a genetic level, the changes in allelic composition over time in a population

# Important considerations

- Individuals do not evolve, they develop - populations evolve
- This was a mistake made by early evolutionists that lead to the rejection of evolution as a process (at least early on)
- Also, it is important to recognize that evolution is not goal oriented.  Changes occur in response to selective pressures in the environment – evolution is opportunistic

# The Theory of Natural Selection

- We are going to look at this from a historical standpoint, with the information available to Darwin during the time of the synthesis
- We will build on this over the course of the class in terms of the observable results and processes associated with evolution by natural selection

# Contributions to Evolution

- During Darwin's lifetime, the concept of change through time was not new. Many people had challenged the proposals of creation and stasis, but there was one major difficulty – a reasonable mechanism
- That is where Darwin found his place as perhaps the most influential biologist of the past two centuries
- Let us look at the information available to Darwin and other scientists of the early 1800s

# The Concept of Evolution

- Although creation and religious thought dominated life for Darwin (he was a student of theology), observations of the world around him suggested a dynamic system rather than stasis
- Additionally, the variation that represents imperfections (?) was much more important than what was originally proposed by other biologists

# Contributions from the Earth

- Two geologists were very influential in the formulation of the theory of natural selection. These were:
  - Hutton – gradualism, which suggests that large changes can be produced by slow, continuous processes and later he proposed uniformitarianism
  - Lyell – uniformitarianism originally proposed by Hutton; this theory incorporated Hutton's work in that the processes we see occurring today, have always been at work yielding the geological formations we see today

# How did this influence Darwin?

- There were two conclusions from these proposals that were essential to the foundation of natural selection:
  - If the formations of the earth are the results of the processes as suggested by Hutton and Lyell, then the earth is certainly much older than originally proposed
  - Secondly, small changes over great periods of time can add up to substantial changes

# An inexplicable phenomenon

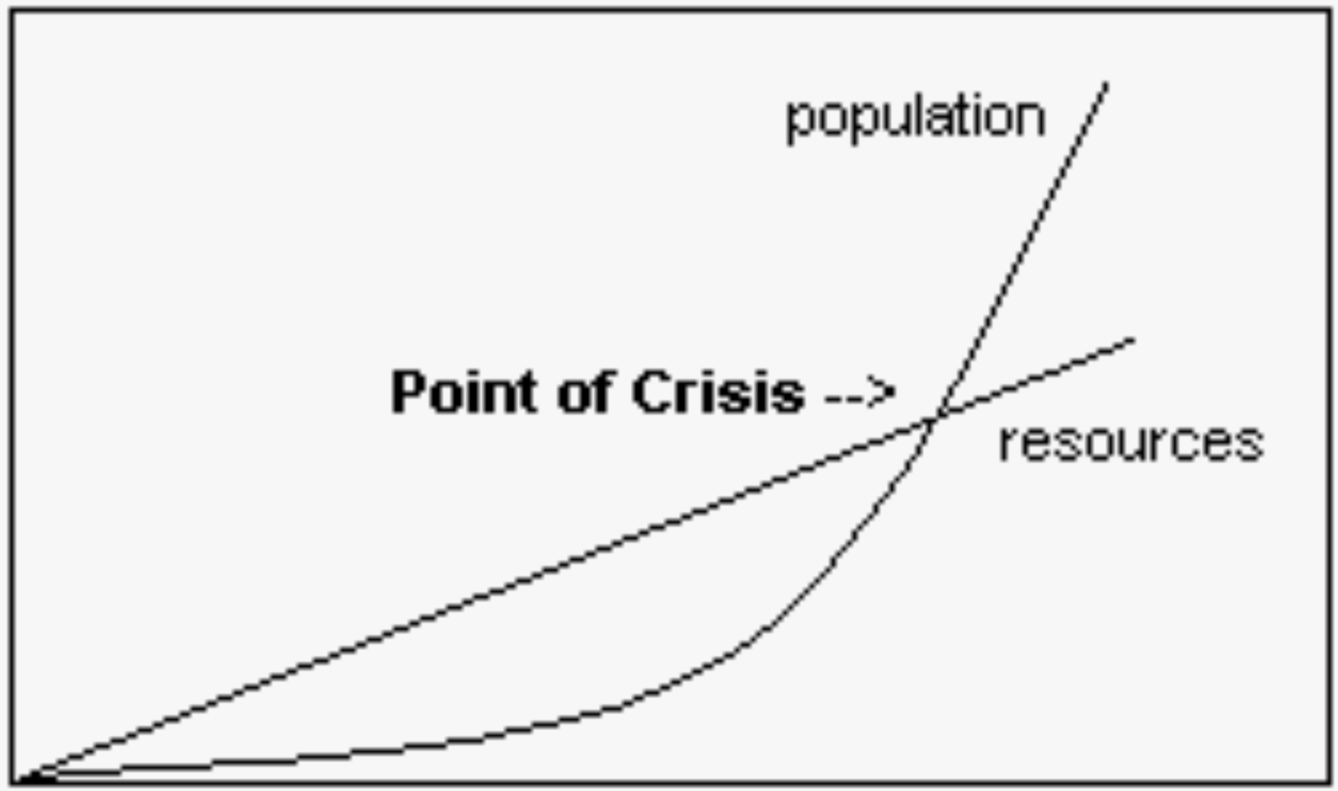
- Some of the most compelling evidence for evolution came from fossil remains. Consideration of fossils ***as*** evidence had been relevant for centuries, but influential individuals had explained their existence away
- Even paleontologists working during Darwin's lifetime ignored the evidence, most notably was Georges Cuvier with his proposal of Catastrophism.

# Another major contributor

- Thomas Malthus also profoundly influenced Darwin when he read the work of Malthus "Essay on the Principle of Population"
- Really the predictions of Malthus were based upon human population growth. The capacity for humans to produce at an exponential rate results in production beyond the ability of the environment to support the growth
- Thus the suffering due to disease, famine, etc. was a direct consequence of the this over-production

# The Malthusian Principle

- The human issues were not necessarily foremost in Darwin's thought, rather the tendency for *all* natural populations to over-produce
- The extension here is that population growth, if left unchecked, would quickly outgrow the available resource base. But, why do natural populations remain at an approximately constant size? That is, what is this ***check*** on growth?




**Malthus' Basic Theory**

# *The(?)* Theory of Evolution

- Darwin was not alone in the recognition of the accumulating evidence that the notion of creation and the youth of earth was not accurate, but only one had provided a comprehensive explanation prior to the proposal of Darwin
- Jean Bapiste Lamark proposed the theory of evolution by acquired characteristics

# The foundation for Lamark

- Like many others, Lamark suggested that organisms must change as environmental conditions change
- The theory basically had two components:
  - The use and disuse of body parts essential for survival
  - The inheritance of these characteristics **acquired during an individuals lifetime**
- However, observations and experimentation resulted in the reject of Lamark's proposals

# Charles Darwin

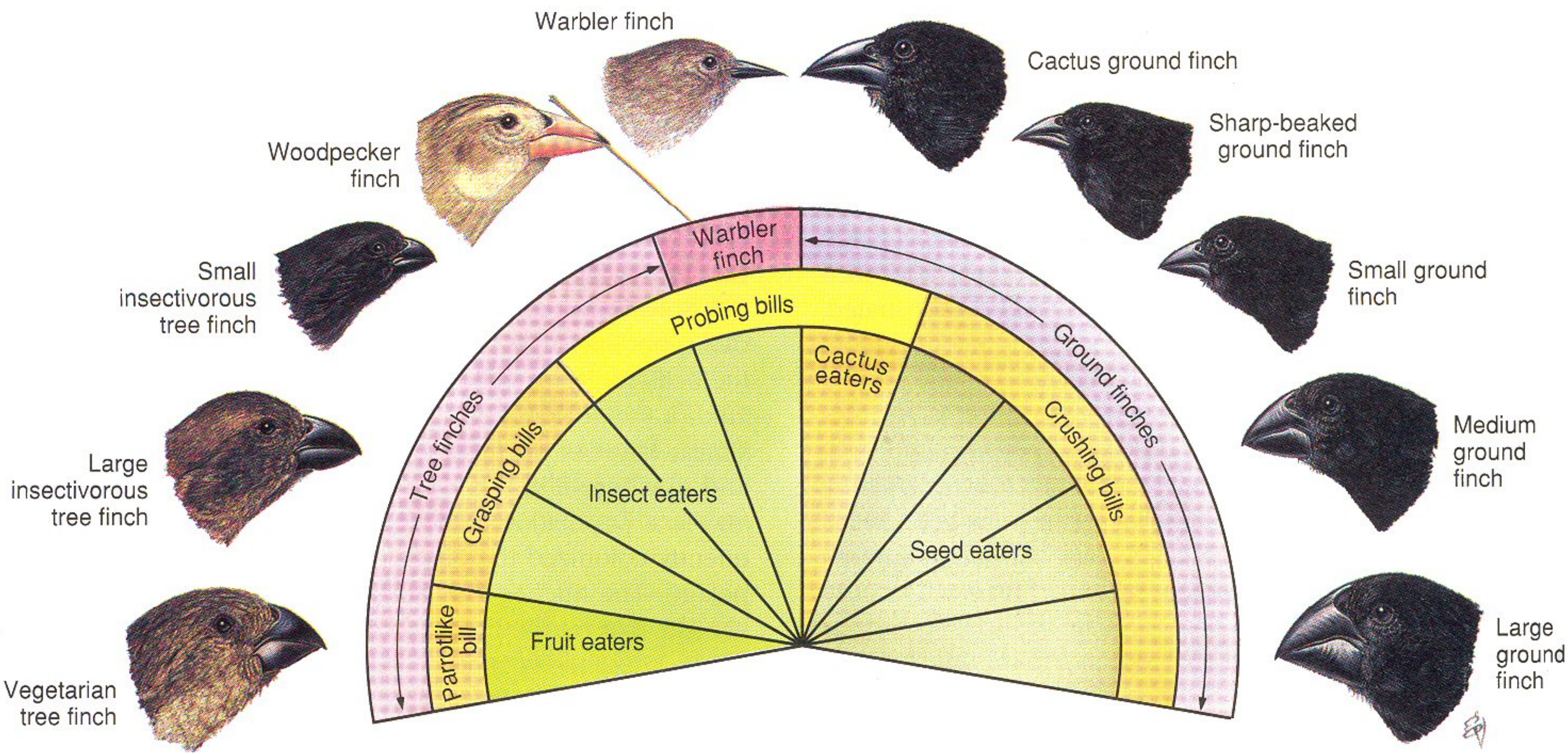
- As the contributions of others helped Darwin in the formulation and questioning of established patterns of thought, his own observations added "fuel to the fire"
- Perhaps most importantly, his position aboard the HMS *Beagle* as the naturalist for the voyage around the world

# The voyage of the HMS *Beagle*

# From the Voyage

- Certain aspects and observations further stimulated Darwin's adaptationist view of life:
  - Similarities of the flora and fauna of South America and relationships among different climatic regimes
  - Similarities of fossil forms found in South America to living South American species
  - The fauna of the Galapagos

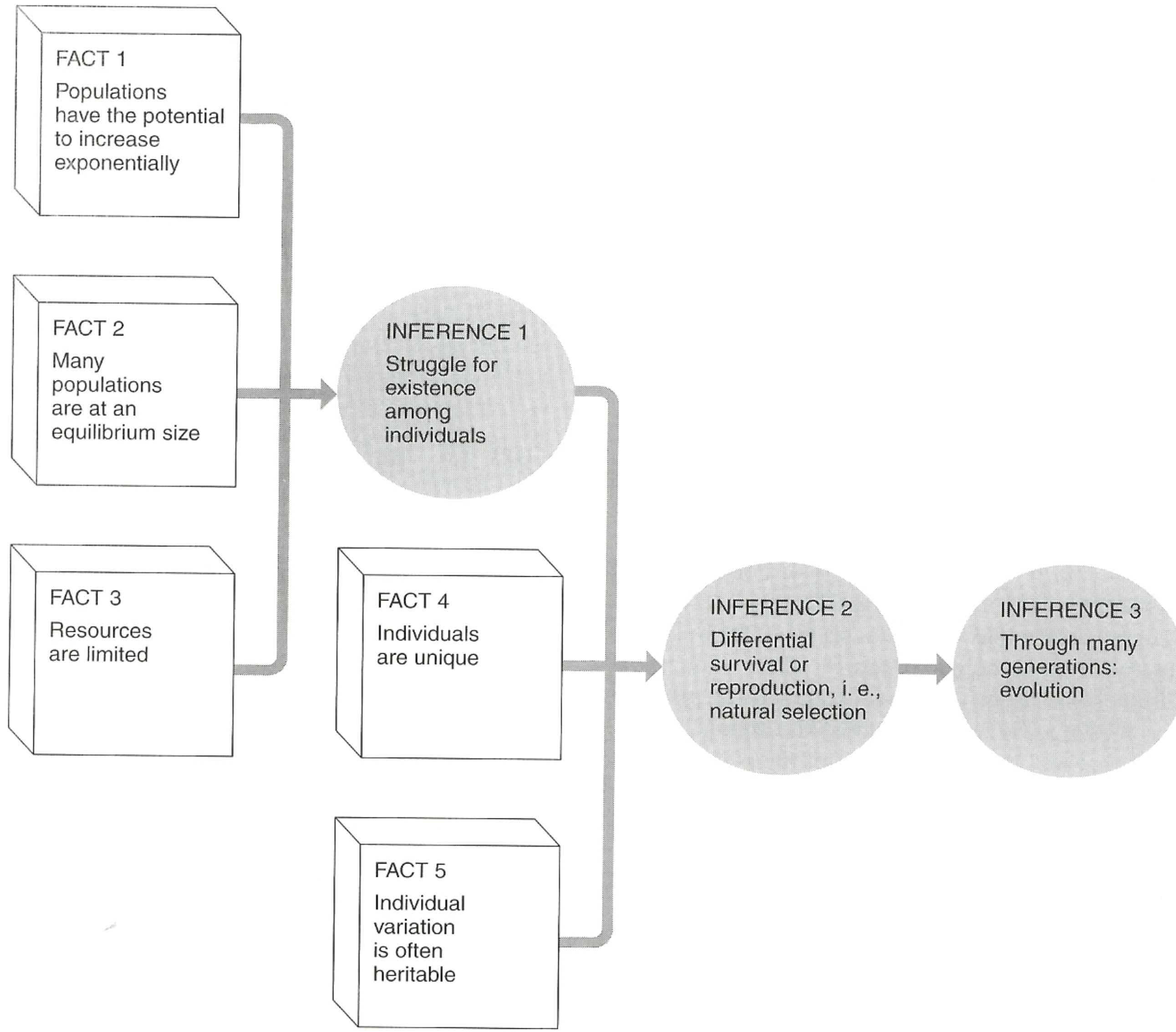
# Most notably, Darwin's Finches



# Darwin at home

- Variability among individuals continued to be an important component of Darwin's thinking. Although individuals of a species look similar, individual variation creates a group of unique organisms
- Also, selective breeding as a practice caught his attention, where artificial selection for characteristics in parents produce offspring with these desired characteristics

# The Great Synthesis



# Now, how did we define evolution?

- Change through time? Yes, but how do we measure this? One method, in fact as defined by some, the only method, is tracking the change of allele frequencies through time
- This definition is too narrow for our purposes, but change through time ***can*** be measured in a variety of ways and this can include phenotypic variation and behavioral responses of individuals and populations

# We need to keep one thing in mind as we evaluate populations

- Change through time is not necessarily only based upon natural selection and adaptation to the environmental conditions
- There are other events that may also change characteristics in populations from generation to generation. These are quite often random events and generally unpredictable. Any ideas?

# We look for stability or predictability

- But, genetic drift, either due to bottleneck or founder events, is one such random process
- Mutational changes – random
- Gene flow, i.e. migration, is generally difficult to predict and certainly does cause changes in the population
- **All of these features may significantly influence the population's features**
- Please read Gould – Evolution of Life on Earth (this is available on-line)

# Tracking change in a population

- The widespread use of molecular techniques has opened the door to evaluating the genotypic distribution within and among populations
- This in turn has allowed us to apply mathematical models to evaluate changes in the genetic structure of the populations – that is, evolution

# Hardy-Weinberg Model

- The Hardy and Weinberg model predicts that allele frequencies and genotypic frequencies will not change in a population unless acted upon by some outside force
- The foundation of the model is in probability and therefore there are some restrictive assumptions, but it is a powerful tool to evaluate change
- What are the assumptions?

# Assumptions of H-W Model

- These will seem very restrictive at first evaluation, but they are:
  - Large population size (minimize effect of genetic drift)
  - No mutations
  - No selection
  - No migration
  - Panmixia
- Now, the model

# Implications of the model

- Regardless of how unrealistic this model is in terms of the assumptions, it is used as a starting point in the analysis of many forms of molecular data to provide a framework for the analysis
- It also provides us with a basic null hypothesis for statistical analyses in the evaluation of change over time
- Additionally, we can build on this model in the evaluation of selective forces to assess the fitness of various genetic components in the population

# Assignment – due on Thursday

- I would like you to take a walk. On this walk, I want you individually to write down a total of six questions – three questions that begin with "How" and three questions that begin with "Why" from any of the areas you may visit
- Then, from this list, provide an answer to one "How" and one "Why" question (~ half page for each)