Section I Outline

Introduction to Course

Ecological Limiting Factors

The Meaning of Adaptation

Ecology and Evolution

Introduction to the study of ecology
Scope of the course

Levels of organization of life

Atoms
Molecules
Compounds
Cells
Tissues
Organs
Organisms (Individuals)
Populations
Species
Communities
Ecosystems
Biosphere

"Ecology" = from the Greek "Oikos" meaning "house", the immediate environment

Term coined by Ernst Haeckel (1869)
(best known for his biogenetic law, "ontogeny recapitulates phylogeny").

Present meaning:
- Study of interactions between organisms and environment
- The economy of nature, the total relations of an organism to both its organic and inorganic environment
- Biotic and abiotic interactions

Levels of interest in modern Ecology

Individual (organism or cell)
- interactions with environment
- interactions between living things

Populations (a group of individuals of one species)
- presence or absence of a species at a given site
- abundance (census)
- change over time

Communities (groups of populations)
- structure
- diversity
- change over time

Ecosystems (groups of communities)
- flux in energy and matter

Modern Ecology is interdisciplinary, a synthetic science that draws from and builds upon the study of genetics, physiology, biochemistry, evolution, and behavior.

Mathematical models are important in the study of ecology because models can help us simplify complex phenomena, and help identify critical variables in complex interactions (such as population growth, competition, and predation).

Types of organisms

Autotrophs
Heterotrophs

Animals
Plants
Protista
Fungi
Monera (Bacteria and Cyanobacteria
Archaea (non-bacterial prokaryotes)

General principles

conformity to the laws of thermodynamics
physical environment controls productivity
ecological communities regulated by population processes
organisms change over time, evolution

Populations are not static. Populations change over time.

Organism distributions

distributions neither random nor homogeneous
most distributions are restricted = patchy
organism often appear to fit their environment

form fits function, why?

Natural selection and evolution

Process of evolution by natural selection requires:

- phenotypic variation
- underlying genetic variation (heritable variation)
- differential reproduction and/or differential survival to age of reproduction (caused by selection)
- differential production of descendants (due to differences between individuals in their interactions with the environment)

Interactions between an individual and its environment result in natural selection, which determines individual fitness.

Organisms in populations change over time = they evolve.

Individuals may be well suited to their present environment, and may be considered "adapted" to their present environment, because it is similar to the environments experienced by ancestors.

Organisms do not evolve for the present or the future, change is a consequence of the past.

Fitness is the relative success of an individual in a given population, and selection is between better and worse. Perfection need not occur.

Yet, there is often a striking match between form and function.

Causes for selection

Darwin's Hostile Forces of Nature (factors that cause selection)
- weather
- climate
- predators
- parasites and diseases
- resources shortages (including mates)

These hostile forces can also described as
- Ecological Limiting Factors
- Limiting Conditions
- Limiting Resources

Conditions
- not consumed or used-up by other organisms
- not made unavailable or less available by other organisms

climate and weather, physical environment, abiotic environmental factors

- temperature
- relative humidity (RH)
- hydrogen ion concentration (pH)
- salinity
- wind speed
- stream water flow velocity
- pollutant concentration

Resources
- something consumed, used, or incorporated or transformed
- something eaten, incorporated in biomass
- using it makes it unavailable or unusable for other organisms
- reuse may occur after a period of use by another organism

- water
- nutrients (C, N, S, K, P)
- minerals
- food
- mates
- shelter
- solar radiation

Major nutrients required by organisms (Ricklefs, 1996, p 41, Table 2.1)

Element	Function
Nitrogen (N)	Structural component of proteins and nucleic acids
Phosphorus (P)	Structural component of nucleic acids, phospholipids, and bone
Sulfur (S)	Structural component of many proteins
Potassium (K)	Major solute in animal cells
Calcium (Ca)	Structural component of bone and of material between woody plant cells; regulator of cell permeability
Magnesium (Mg)	Structural component of chlorophyll; involved in the function of many enzymes
Iron (Fe)	Structural component of hemoglobin and many enzymes
Sodium (Na)	Major solute in extracellular fluids of animals

Solar radiation: a critical resource

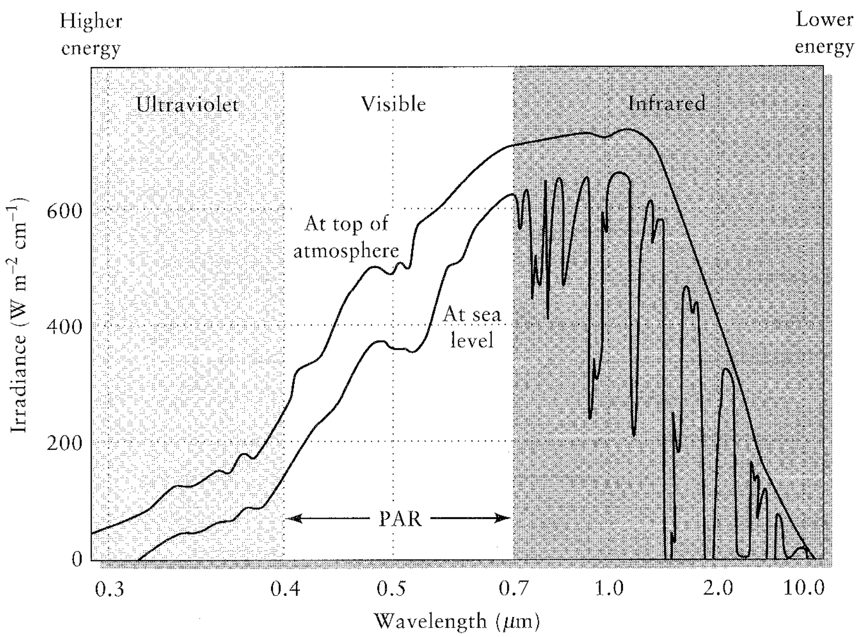
- arriving energy varies with latitude
  - highest at the equator (see Ricklefs, 1996, pp 80 and 81, Fig. 4.1 and 4.2)
  - varies with degree of atmospheric scattering and reflection

- at leaf surface light can be
  - reflected
  - filtered and transmitted
  - absorbed

- eukaryotic chloroplasts absorb light between 380nm and 710nm
  - visible light spectrum
  - 56% of incident radiation is outside visible range
  - photosynthetically active radiation (PAR) (~400nm - 700nm)

- prokaryotic chlorophylls: absorption peaks at 800nm, 850nm, and 870-890nm

Spectral distribution of sunlight (Ricklefs, 1996, p 45, Fig. 2.13)



Biological energy flow is an open system, not a cycle

Major energy transformation processes

Cellular respiration

$$C_6H_{12}O_6 + 6O_2 \text{ >>>>>>> } 6CO_2 + 6H_2O + \text{energy (ATP)}$$

Photosynthesis

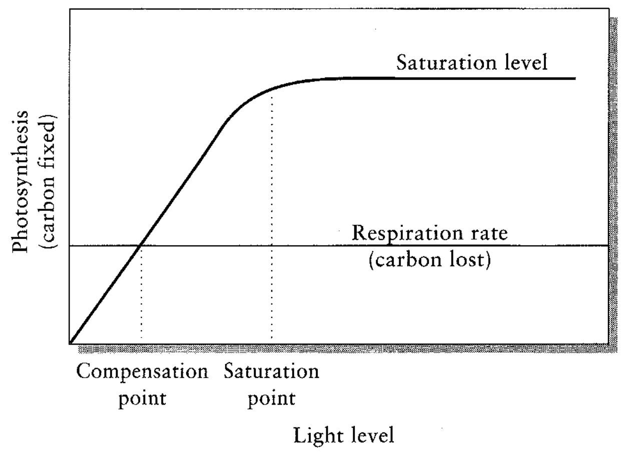
$$6CO_2 + 12H_2O + \text{energy (709kcal) >>>>>>>> } C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Light intensity (energy/unit time/unit area) (Ricklefs, 1993, p 39, Table 2.2)

Measurement	Units	Typical value
langley (ly)	1 cal cm^{-2}	700 ly d^{-1}
watt (W)	1 J s^{-1}	1000 W m^{-2}
einstein (E)	6×10^{23} photons	2000 μE m^{-2} s^{-1}
		200 nE cm^{-2} s^{-1}

Source: M. G. Barbour, J. H. Burk, and W. D. Pitts, *Terrestrial Plant Ecology.* Benjamin Cummings, Menlo Park, Calif. (1980).

Photosynthesis rate as a function of light intensity. The compensation point is the light intensity at which the rate of photosynthesis just compensates for the maintenance needs of the organism (cell respiration rate) (Ricklefs, 1996, p 46, Fig. 2.15).



Water absorbs light energy and scatters light

In sea water: At 10m, the energy of visible light decreases 50%
At 100m, the energy of visible light decreases to <7%

Red is absorbed first
Blue and violet scatter easily
Green penetrates water best

Euphotic zone: Depth to which photosynthesis exceeds respiration in water.

Rarely the compensation point, the bottom of the euphotic zone, is as deep as 100m.

Examples, very clear ocean or lakes near equator.

In highly turbid waters, the compensation point may be reached at 1m.

Major Essential Elements

Calcium (Ca), Iron (Fe), Nitrogen (N), Magnesium (Mg), Potassium (K), Phosphorus (P), Sodium (Na), Sulfur (S)

Limiting Nutrient Elements

In aquatic (freshwater) environments: nitrogen and phosphorus
In marine (saltwater) environments: iron
In terrestrial environments: nitrogen and phosphorus (calcium)

Other Essential Resources

Carbon Dioxide: Not limiting
Oxygen: Can be limiting in water
Water: Often limiting in terrestrial environments

Limitations for one essential resources can influence the availability of other essential resources. This is the case among terrestrial plants for the relationships between photosynthetic rates, water loss, and gas exchange.

Photosynthetic Capacity and Water Conservation

Photosynthesis rate varies widely among species (100x) even with light saturation and all other resources in abundance. This variation is due in part to differences between plant species in the biochemistry of carbon fixation in photosynthesis (Calvin Cycle). Plants can be categorized as having C_3, C_4, or CAM metabolism.

Photosynthetic Rate, Water Loss and Gas Exchange
Specializations and Compromises Among Plants

1. Short life, high photosynthetic rate when water abundant, dormant at other times (seed stage) (desert annuals)

2. Long life, leaves produced when water abundant, leaf drop during droughts (winter or dry season) (deciduous woody plants)

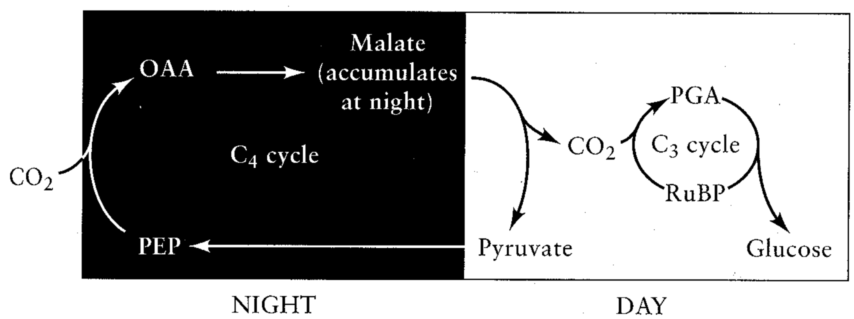
3. Leaves long lived, transpire slowly, tolerate water deficit but have low photosynthetic capacity (woody evergreens, evergreen desert shrubs)

4. C_4 photosynthesis: increased efficiency of carbon dioxide use per unit of water loss, but inefficient at low light intensity (not shade tolerant), high temperature optima, adaptation for water conservation and efficient nutrient capture (arid, tropical, and saline environments) (see figures on next page)

5. CAM photosynthesis (Crassulacean Acid Metabolism): control of water loss by limiting atmospheric carbon dioxide capture to night hours when water transpiration rates are at a minimum, stomata are open at night and are closed during the day, good water conservation but there are limits on photosynthetic capacity (arid, high elevation, windy environments)

Crassulasian Acid Metabolism (CAM)

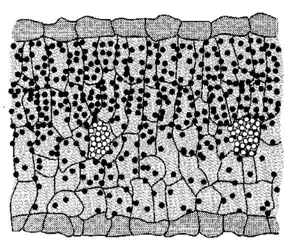
Major steps in the capture of carbon dioxide in CAM plants. Atmospheric carbon dioxide is brought into the plant at night, when the stomata are open. In the daytime, stored reserves of malic acid and oxaloacetate are broken down to release carbon dioxide inside leaves for use in the Calvin Cycle, but gas exchange to the atmosphere is minimal. Abbreviation key: RuBP = ribulose bisphosphate (a 5C compound), PGA = phosphoglycerate (two molecules of a 3C compound), PEP = phosphoenolpyruvate (a 3C compound), OAA = oxaloacetate (a 4C compound), Malate = malic acid (a 4C compound). Water loss is controlled in this system by mean of temporal separation of carbon dioxide capture from the atmosphere and the addition of one carbon to RuBP in the first step of the Calvin Cycle (Ricklefs, 1996, p 69, Fig. 3.9).

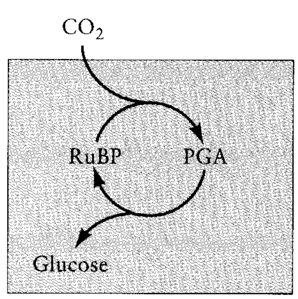


C_4 Photosynthesis

Comparison between C_3 and C_4 plants showing the differences in the physical distribution of chloroplasts in the leaves, and differences in first steps of atmospheric carbon dioxide capture for photosynthesis. Abbreviation key: RuBP = ribulose bisphosphate (a 5C compound), PGA = phosphoglycerate (two molecules of a 3C compound), PEP = phosphoenolpyruvate (a 3C compound), OAA = oxaloacetate (a 4C compound), Pyr = pyruvate (a 3C compound). Water loss is better controlled in C_4 plants by physically separating carbon dioxide capture from the atmosphere and the addition of one carbon to RuBP in the first step of the Calvin Cycle. Water loss is minimized in this system because the atmospheric carbon dioxide capture step is catalyzed by the enzyme PEP carboxylase which has a higher affinity for carbon dioxide than does the enzyme RuBP carboxylase (Ricklefs, 1996, pp 68 and 69, Fig. 3.7 and 3.8).

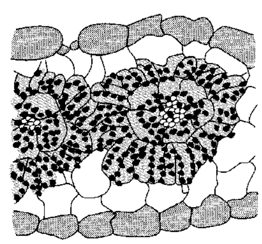
C_3 Plants

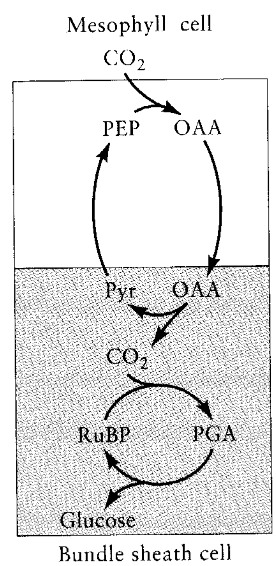




Mesophyll cell

C_4 Plants





Bundle sheath cell

Ecological Niche (Hutchinson, 1957)

The set of conditions and resources minimum and maximum values that are limiting to a population of a given species. This is an *n*-dimensional hyperspace.

The fundamental niche is the niche defined by abiotic factors alone.

The realized niche is the fundamental niche with biotic factor limitations superimposed. The realized niche is typically smaller than the fundamental niche.

Two or three-dimensions are typical in niche descriptions (see Ricklefs, 1996, p 107, Fig 5.4)

Limiting Conditions and Resources
Generalizations

1. Lethal conditions may limit distributions but such conditions need only occur occasionally.

2. Distributions are more often limited by regularly suboptimal conditions (rather than lethal) leading to reductions in growth, reproduction, or increased predation.

3. Sub-optimal conditions act by altering outcomes of biological interactions.

4. Sub-optimal conditions often interact with other factors (determining which single condition is critical can be difficult).

5. At the edge of a species distribution, individuals occupy patches most like the conditions in the center of that species range.

6. Evolutionary responses tend to modulate effects of suboptimal conditions.

Ecology and Evolution

What is changing as a result of evolution? Phenotypes

Changes in phenotypes is reflected in qualitative and quantitative aspects of interactions between organisms and their environment.

What is the phenotype? Any aspect of an organism except the information encoded in the genetic materials (genotype).

Genotype + Environment >>>> yields>>>>>>>Phenotype

Phenomena of special interest:

Organic diversity: number of different species

Patterns in nature: distribution and abundance

Adaptation: close fit between form and function
aspects of phenotypes seem formed for specific functions
products of evolution by natural selection

Evolution is change in phenotypes over time, long term change

Involves changes in gene (allele) frequencies in a population

Evolution is measured in population change, cumulative genetic change is the result which is reflected in phenotypic change.

Importance and Sources of Phenotypic Variation

Natural selection occurs when there is phenotypic variation regardless of the source, but only variation with a genetic basis (phenotypic differences caused by genotypic variation) can be the source of evolutionary change.

What causes phenotypic variation?

Since the phenotype is the product of an interaction between information, the genotype, and the environment, variation in either genotypes or environments can cause variation in phenotypes.

All traits have a genetic background but not all differences between individuals are due to genetic differences.

Imagine a plant species with mono-hybrid genetics for height, semi-dominant allelic interactions (dosage effects), and strong environmental effects on height.

Given a population that is isogenic (all individuals have the same genotype) and homozygous, there will still be variation in height, but the variation will be due entirely to environmental variation.

Given another population with two alleles, **A** and **a**, in equal frequency and given random mating within that population, there should be three genotypes produced in ratios of 1:2:1 as given below (so population is polygenic, has more than one genotype):

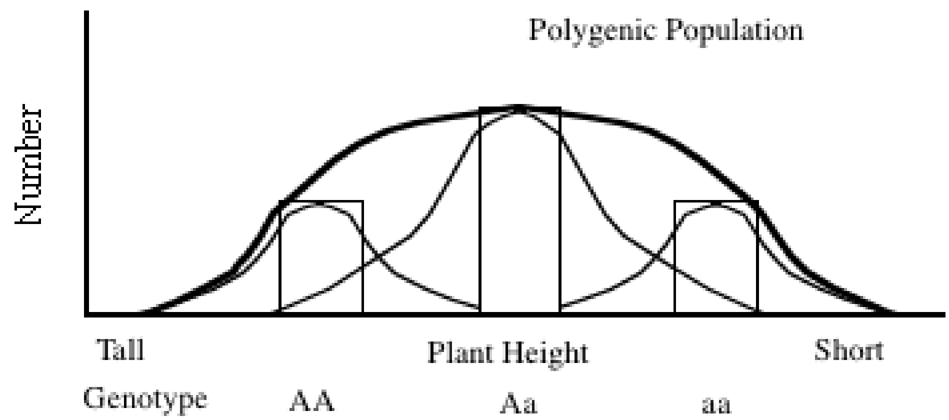
Alleles for plant height: **A** tall information **a** short information

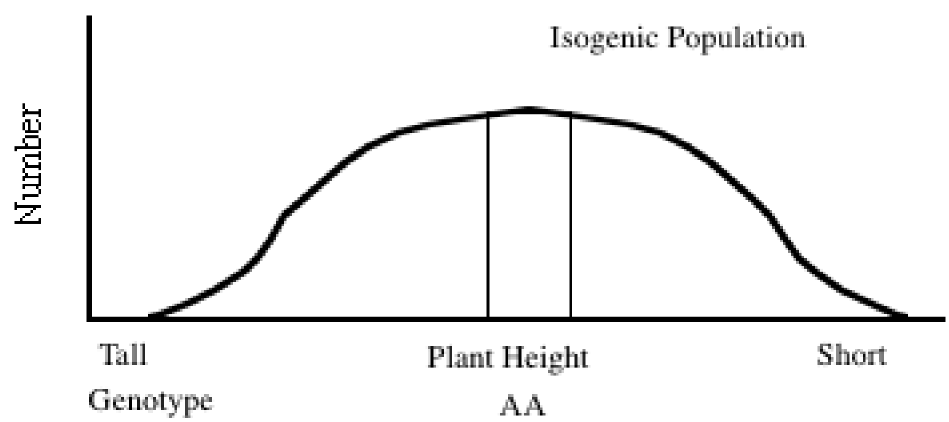
Genotypes:	**AA** tallest information	**Aa**	**aa** shortest information

Allele frequencies: f(**A**) = 0.5 f(**a**) = 0.5

Genotype frequencies: f(**AA**) = (0.5)(0.5) = 0.25
f(**Aa**) = 2(0.5)(0.5) = 0.50
f(**aa**) = (0.5)(0.5) = 0.25

Frequency histograms for plant height in isogenic and polygenic populations with strong environmental influences on phenotypic expression.



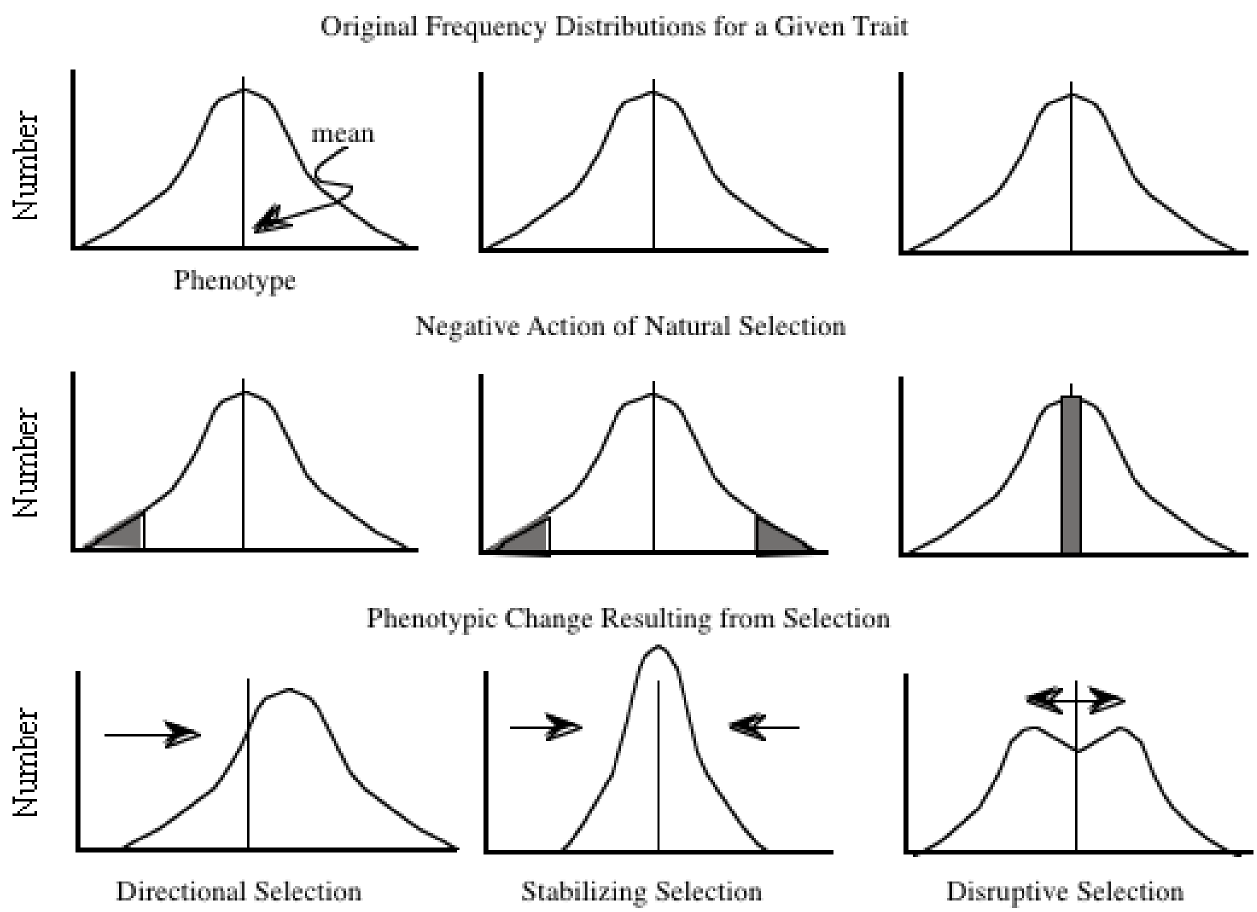


Note that both populations exhibit very similar phenotypic variation, frequencies of specific heights, indicated by the darker outline curve.

Selection can and will occur in both isogenic and polygenic populations.
No phenotypic change can occur in the isogenic population as a result of selection. No evolution can occur in the isogenic population.

Only selection on traits whose variation has a genetic basis (polygenic population, heritable variation) can result in phenotypic change = evolutionary change.

Forms of selection and resulting forms of evolution. The frequency distributions show how populations respond to selection assuming that the observed phenotypic variation results, in part, from genotypic variation (polygenic populations). The shaded area of each distribution indicates the negative action of selection, for example predation on the tallest individuals in a population.



Arrows indicate the direction of phenotypic change for each form of selection.

The causes for natural selection, the causes for differential survival and reproduction, are the hostile forces of nature (limiting resources and conditions).

Examples of directional selection and directional evolution:
antibiotic resistance evolution in gonorrhea, TB, *Salmonella*, *Shigella*
pesticide resistance evolution in malaria mosquitos (*Anopheles*), boll weevils
herbicide resistance evolution in agricultural weeds

Example of stabilizing selection and stabilizing evolution:
sickle cell hemoglobin and malaria resistance in humans

Example of disruptive selection and disruptive evolution:

Adaptations are products of evolution by natural selection.

Adaptations are features of an organism that enable it to confront the Hostile Forces of Nature.

The functions of adaptations are survival and reproduction.

Does Natural Selection have a goal? No, selection does not have a specific goal.

Selection acts on the phenotypic variation that is present, the best of the alternatives available is the phenotype that is most successful.

The best alternative phenotype depends entirely on the Hostile Forces of Nature at a given place and time and the other phenotypes that are present.

Example of Evolution and Natural Selection
Industrial Melanism, Cryptic Coloration, and Environmental Change

Organism: Peppered Moth, *Biston betularia*

Variation in wing and body color and color pattern (see Ricklefs, 1996, p 383).

Light color morph: white or light tan color wings and body with dark markings (spots and irregular lines, somewhat like pepper sprinkled on paper).

Dark color morph: dark brown or black body and wings (melanistic form).

This variation has a genetic component and involves a single gene. Spontaneous mutation in both directions occurs at low frequency, so dark morph parents rarely produce light morph offspring and light morph parents rarely produce dark morph offspring.

In pre-industrial England, the light morph dominates in the collections of natural historians, and tree trunk (natural perches for this moth species) are covered with lichens making the perches light in color.

Based on extensive natural history collections made in Manchester, England:

1848 first dark morph specimens captured in Manchester area.
1895 collections consist of 98% dark morph

During this same time, pollution from coal burning (industrial revolution) was killing lichens on tree and covering tree trunks with soot.

1937 E.B. Ford proposed that differential predation on dimorphic moths depends on the color of the perches.

1950 H.B.D. Kettlewell performed experiments to test the hypothesis that the change in moth color morphs was due to natural selection (differential predation).

Hypothesis: Cryptic (camouflaged) moths will be at lower predation risk than non-cryptic moths.

Environment (Perch Color)		
	Polluted (Dark Perch)	Non-Polluted (Light Perch)
Dark Morph	More Cryptic Lower Predation Risk	Less Cryptic Higher Predation Risk
Light Morph	Less Cryptic Higher Predation Risk	More Cryptic Lower Predation Risk

Prediction: Birds take non-cryptic morphs more frequently than the cryptic morphs.

Predation on Moths by Birds		
	Light Morph	Dark Morph
Polluted Forest	43 (74%)	15 (26%)
Non-Polluted Forest	26 (14%)	164 (86%)

Hypothesis: Cryptic (camouflaged) moths will survive longer in nature than non-cryptic moths.

Prediction: When both moth morphs are marked and released in nature, the more cryptic morph will be more readily recaptured than will the less cryptic morph.

	Polluted Forest		Non-Polluted Forest	
	Light Morph	Dark Morph	Light Morph	Dark Morph
Moths marked and released	201	601	496	473
Moths recaptured	34	205	62	30
Percentage recaptured	16%	34%	12.5%	6.3%

A given trait may be an adaptation in one environment and not in another.
Mutation keeps reintroducing the rare color morph in all populations.

Natural Selection does **not** have a goal.

Differential survival and reproduction simply occurs among the individuals in a given population. The outcome of selection depends on the specific environment at a given place and time, and the phenotypes present in a given population.

Natural selection is not the only means by which evolution can occur.

Potential causes for evolutionary change are:

1. Natural Selection
2. Mutation (random process, but the source of all variation)
3. Drift (random process)
4. Migration (random process)

Natural selection is the principal guiding force in evolution.

1. Altering the direction of selection alters the direction of change.
2. Causes of mutation are independent of the causes for selection.
   Mutation does not guide change.
   Mutations do not respond to need.
3. Only the causes for selection remain consistently directional for long time periods.

What is the purpose of life?
Is there a singular goal? No
Is there a singular consequence? Yes

If evolution by natural selection is the major force molding phenotypes then:

All organisms must be striving to do one thing, maximize their genetic representation in future generations.

There is no single best means of achieving this, but in general, organisms are **selfish**.

Natural Selection and Selfish Phenotypes

"Natural Selection cannot possibly produce any modification in a species exclusively for the good of another species; though throughout nature one species incessantly takes advantage of, and profits by, the structures of others... If it could be proved that any part of the structure of any one species had been formed for the exclusive good of another species, it would annihilate my theory, for such could not have been produced through natural selection." (Darwin's Challenge)

Charles Darwin, 1859, The Origin of Species

Yet, organisms do not always seem to behave selfishly!

Swollen thorn acacia plants, *Acacia collinsii* and *A. cornigera*, in Central America, and acacia ants, *Pseudomyrmex* spp., found in association with these plants, have some unusual characteristics.

Swollen thorn acacias are trees and shrubs that:

- produce and hold leaves year-round, unlike closely related plants that are deciduous and drop leaves in the dry season (leaves provide year-round shelter for acacia ants) (see Ricklefs, 1996, p 415, Fig. 18.14)
- produce swollen thorns on stems, much larger than those found on other *Acacia* species (used as nesting sites by acacia ants)
- produce Beltian bodies, leaf tip protein and lipid structures which seem to serve no function for the plant (collected by acacia ants and fed to ant larvae)
- produce extrafloral nectaries year-round, nectar (carbohydrate and water) production at the base of leaf petioles, which are not important in attracting pollinators (nectar is used as food by the acacia ants) (see Ricklefs, 1996, p 416, Fig. 18.15)

These structures are produced by the swollen thorn acacia apparently for the exclusive good of the acacia ants.

Acacia ants live their entire lives associated with a given swollen thorn acacia plant. The ants provide the swollen thorn acacia plant with:

- competitor removal, seedlings that sprout under the canopy of a given acacia plant are cut-down by the ants from that acacia and branches of other plants that touch the acacia plant are cut-back
- herbivore protection, unlike other *Pseudomyrmex* species which are diurnal, acacia ants are active 24 hours and prevent and discourage herbivory (by both insects and vertebrates) on the acacia plant they occupy

This is an example of a mutualism. The swollen thorn acacia survive better when the ants are present than when the ants are absent. The swollen thorn acacia ants do not live anywhere but in acacia thorns. Each species is ultimately behaving selfishly because they benefit from the aid they give to the other species.

Types of Interactions			
	Benefit	Harm	No Effect
Benefit	Mutualism	Predation	Commensalism
Harm	Predation	Competition	Amensalism
No Effect	Commensalism	Amensalism	Neutralism

Are all organisms biologically selfish? Does this general consequence extend to the molding of individual phenotypes? Are individual organisms selfish?

How do individuals reproduce?

An individual may influence allele frequencies in future generations by:

1. Production of offspring by that individual (direct reproduction).
2. Influencing the survival and reproduction of individuals carrying genes identical by descent (indirect reproduction). These influences are called Inclusive Fitness Effects (W.D. Hamilton, 1964) or Kin Selection.

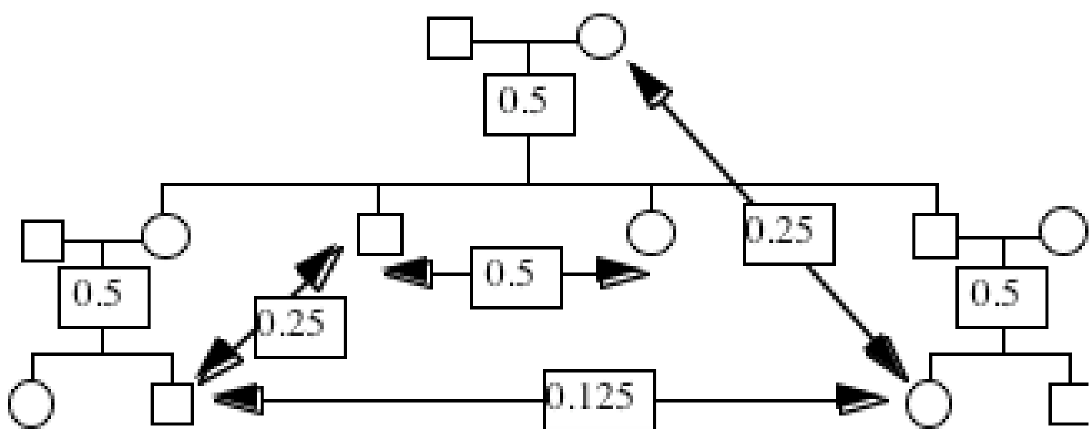
Examples of Inclusive Fitness Effects:

- Parental care
- Helpers at the nest, cooperative breeding (birds and mammals)
- Eusocial insects (Hymenoptera, Isoptera)
- Aposematic coloration

Inclusive Fitness Effects

Individuals carrying genes identical by descent are relatives (family members).

Genetic relationships can be expressed as the coefficient of relationship (*r*), the proportion of genes identical by descent.



Inclusive Fitness Effects

Given sexually reproducing, diploid organisms:

Relationship Type	Coefficient of Relationship(r)
Parent - Offspring	0.5
Full Siblings	0.5 on average (range 0 - 1.0)
Grandparent - Grandchild	0.25
Uncle (Aunt) -Nephew (Niece)	0.25
First Cousins	0.125

Altruism: Behavior benefiting another individual while being detrimental to the individual providing the benefits. Benefits and detriments are defined in terms of survival and reproduction.

"Altruism" is defined in much the same way that Darwin's Challenge is framed. This is behavior that we predict cannot be produced by natural selection.

Aiding relatives is an alternative means of individual reproduction, which depends on:

1. The magnitude of r. The greater the value of r, the more likely
2. Magnitude of benefit to aid receiver (includes reciprocity).
3. Magnitude of cost to aid giver (depends on alternative activities).
4. Magnitude of benefit to aid giver from sources other than the aid receiver.

Natural selection molds phenotypes. Behavioral traits may appear selfish or altruistic, but all are ultimately selfish in an evolutionary sense.

Can altruism evolve by means of natural selection?

Imagine a cleaner fish species in which individuals get no benefits from cleaning parasites from other fish species, but cleaners did sustain some costs. If there were variation in the cleaner fish population so some individuals were cleaners and others were non-cleaners, and the variation was heritable, which behavioral trait would be most successful in leaving descendents?

If the process of evolution by natural selection applies to all organisms, then it must apply to human too. A vulgar theory? Does it apply to humans?

Does altruism occur in human behavior?

adoption, life saving, anonymous gifts

Behaviors that appear to make no sense today may have clearly been biologically selfish in their original context. Humans are not living in the environments in which we evolved, physical or social. Context (environment) is essential for understanding the evolution and maintenance of phenotypic traits.

An evolutionary view of life provides a framework for interpreting ultimate function, the origin of phenotypes, structure and function. The theory of evolution by natural selection enables us to interpret how phenotypes were molded to their present state, but this theory does not indicate what should be.

Speciation

Species Definition: Biological Species Concept

A species is a population (or group of populations) within which there is interbreeding in nature, but this group is reproductively (genetically) isolated from other such populations or groups.

Species are natural-biological groupings.

In practice, groupings are based on easily identified aspects of phenotypes. The biological species concept is limited to sexually reproducing organisms. A given species identification is not precise because our knowledge about interbreeding and gene flow between groups is not perfect. Populations are not continuous. Within populations there can be spatial isolation (separation in space) or temporal isolation (separation in time).

Species Formation
Reproductive isolation = barrier to gene flow
One population splits into two populations

Forms of Isolation

Allopatric: geographic or allopatric speciation, physical isolation

Changes occur in isolation in response to local conditions and chance events. The form of physical isolation necessary for reproductive isolation depends on the particular organism involved.

Parapatric: parapatric speciation

Reproductive isolation among members of a continuous population without geographic barriers. Isolation involves environmental discontinuity, such as a soil type change for plant species or host plant change in an herbivore.

Sympatric: sympatric speciation

Speciation with overlapping distributions among the two populations that are becoming isolated. Isolation may be spatial or temporal.

Polyploidy formation in plants (rare in animals)
- autopolyploidy - within a species
- alloploidy - between species

Host races
- insects returning to natal plant species to reproduce

Reproductive habitat races
- fishes and amphibians that return to the site habitat to

What happens in isolation?

Isolation alone does not make organisms different from each other:
- reproductive behavior changes
- temporal or spatial reproductive changes
- physiological changes

Small differences can be magnified at recontact between groups if hybrids are less viable than either "pure" type. This phenomenon is termed character displacement (to be considered in detail in section on competition). Even when phenotypic differences are great, genetic differences can be very small.

Higher level systematics are groupings of species based on phenotypes (similarities and differences, shared characteristics) that are hoped to reflect evolutionary descent relationships:

- Species grouped in a Genus
- Genera grouped in a Family
- Families grouped in an Order
- Orders grouped in a Class
- Classes grouped in a Phylum
- Phyla grouped in a Kingdom

Macro-evolutionary Phenomena

Long-term evolutionary change at higher level systematic categories is termed macro-evolution (geological time scale).

- Speciation: one species subdividing (diverging) to two species
- Phyletic evolution: change within a single line of descent
- Extinction: termination of a given line of descent

Extinction

In geological time, there have been six major periods of mass extinction:

500 million years ago	Cambrian, extinction of 50% of animal families
345 million years ago	Devonian, extinction of 30% of animal families
230 million years ago	Permian, extinction of 50% of animal families extinction of 95% of marine species
180 million years ago	Triassic, extinction of 35% of animal families
65 million years ago	Cretaceous, extinction of dinosaurs, 70% of animal species
10,000 years ago	Pleistocene, extinction of large mammals and birds

Causes of mass extinctions

- major events in continental drift, mountain building periods, volcanic activity
- sea level lowering, exposing continental shelves
- asteroid/comet impacts (100 million year intervals)
- human activity, explosions, habitat destruction, overutilization, overhunting
- long term cycles in earth orbit and sunlight intensity

Biological factors influencing likelihood of extinction:

- rarity
- dispersal ability
- degree of specialization
- population density variability
- trophic status
- longevity
- intrinsic rate of population growth

Section I Review Problems and Sample Examination Questions

1. The sexually transmitted disease, gonorrhea, is caused by the bacterium *Neisseria gonorrhoeae*. This disease used to be treatable with the antibiotic penicillin. Penicillin was widely prescribed for that purpose and was even dispensed to individuals thought to be at risk of infection who were not actually infected. In 1970, the first strains of penicillin resistant *Neisseria* were isolated from patients with gonorrhea. In 1985, the percentage of gonorrhea cases in the United States caused by penicillin resistant *Neisseria* was 1% (9000 cases of penicillin resistance) but by 1990 the percentage had increased to almost 9% (59,000 cases of penicillin resistance). The percentage of *Neisseria* infections that are resistant to penicillin continues to increase.

Describe the roles of mutation and natural selection in the phenotypic change observed in *Neisseria gonorrhoeae*.

What kind of selection occurred in *Neisseria gonorrhoeae* populations? Draw a frequency histogram to illustrate your answer.

List and describe the requirements for evolution by natural selection.

2. Extinction is a macroevolutionary process in which all individuals in a given group (species) stop leaving descendents, and eventually disappear. Is this an important phenomenon in the history of life on earth? Explain.

Name five factors that may increase the likelihood of extinction.

3. What is the function of photosynthesis specializations such as C_4 photosynthesis and CAM in some plant species? Explain your answer.

4. Name and describe Darwin's Hostile Forces of Nature. What is the relationship between the Darwin's Hostile Forces and ecological limiting conditions and resources? What is the role of the Hostile Forces and limiting factors in the process of Natural Selection?

5. What is the compensation point in photosynthesis? Under what circumstances in nature would photosynthetic organisms be at the compensation point? Draw a fully labeled graph showing the rates of photosynthesis and respiration (as dependent variables) to help illustrate your answer.

Multiple Choice (choose the one best answer)

6. Compared to C_3 plants, C_4 plants are able to:
   a. reduce water transpiration from leaves
   b. capture carbon dioxide at a faster rate
   c. separate carbon fixation from the Calvin Cycle
   d. all of the above

7. Speciation requires some form of isolation between populations because:
   a. all evolution requires geographic isolation
   b. species are defined by reproduction isolation
   c. mutation will occur most rapidly in isolation
   d. evolutionary forces are too weak in sympatry

8. The causes for natural selection are known as:
   a. limiting conditions
   b. resource shortages
   c. hostile forces of nature
   d. all of the above

9. One of the requirements for the occurrence of natural selection is phenotypic variation. In the absence of phenotypic variation, evolution:
   a. cannot occur by natural processes
   b. may occur by disruptive selection
   c. cannot occur by natural selection
   d. cannot occur by molecular processes

10. Changes in populations of many species of gut inhabiting bacteria during the past 20 years in which cells have become resistant to almost every known antibiotic is an example of:
   a. mutation directing phenotypic change
   b. selection causing phenotypic change
   c. antibiotics causing mutational change
   d. all of the above

11. Oxygen gas is essential for cellular respiration in most organisms yet this gas is readily available in terrestrial environments. In terrestrial environments, oxygen can therefore be considered:
   a. a limiting resource
   b. a required resource
   c. a biotic condition
   d. an abiotic condition