

Lecture 10 – Evolution in Action

Human Immunodeficiency Virus

Central Dogma of Biochemistry: DNA → mRNA → protein

Retrovirus

- RNA and to DNA (reverse direction)
- uses reverse transcriptase (error prone, no checking mechanisms)
- no proof reading enzymes
- very high mutation rates – million times greater than typical human DNA mutations

HIV

- infects and hijacks immune cells with virions, whose DNA is replicated with host machinery
- As viral load (HIV RNA copies) increases ~10 years the immune system helper T-cells decrease in concentration
- 9 protein coding genes (human 23-25 thousand)

Viral DNA

- spliced into host chromosomes
- transcribed to mRNA
- viral protein transduced
- virions produced; spread
- new hosts infected

AZT

- blocks reverse transcriptase as a thiamine mimic that does not function in transcription (N₃ instead of OH group)
- Mutations soon lead to virus with AZT resistance (can work with N₃ group)
- Whole population of HIV now more resistant to AZT
- AZT resistance is heritable
- Alternatives to AZT – nucleoside reverse transcriptase inhibitors, integrase inhibitors, protease inhibitors

Viruses

- Epitopes – viral coat proteins
- Delta-32 allele deletion in Scandanavia (bubonic plague?) confers resistance to HIV. 1 deletion some resistance; 2 deletions almost total resistance
- Is a virus alive? Not cellular, can't reproduce with its own machinery.
- viral vaccines prep immune cells to recognize epitopes (viral coat proteins) ahead of time
- epitopes can rapidly evolve – functions? ID?

Host parasite evolution

- host evolves resistances
- parasite evolves more virulence.. or does it? Should it?

Evolution

- gradual change in the characteristics of a population over time, from selection (natural)

Summary

- evolution can be very fast
- even non-living (virus) things can evolve
- HIV evolution highlights – mutation, variation, selection, evolutionary history

Darwin's Central Ideas

- individuals vary greatly in heritable traits
- any population can produce far more off-spring than their habitat can support
- some individuals have traits that give them a survival advantage – reproduce more and pass on genes
- as genes are passed on the incidence of related traits changes

Adaptive radiation

- same species new forms (bush and tree)

Adaptive zone

- land, oceans, ecosystem niche

Islands

- show-case evolution and adaptive radiation (founder events)

Famous adaptive radiations

- insect traps (plants, fungi, spiders)
- wings (birds, bats, insects, pterosaurs)
- re-invasion of oceans (twice by reptiles and mammals)

Polygenic traits

- multiple genes encode or contribute to a single trait

Lecture 11 – Postulates of Selection

Darwin's postulates of selection

- 1- individuals vary greatly in heritable traits
- 2- populations produce more offspring than can survive
- 3- some survive, those with higher fitness/survival advantages and they reproduce more
- 4- as their traits are passed on preferentially, the over frequency of traits (and genes) changes

- 1- variation exists in a trait
- 2- the trait is at least partly heritable
- 3- variation in survival fitness and reproductive fitness exist too
- 4- variation in fitness is related to variation in the trait

Darwin's Finches

- variation in beak depth relates to variation in diet (seed types preferred)
- seed availability changes with rainfall
- distribution of individuals with small and large (medium?) beak depths
- evolution doesn't happen in one dry season – must be over generations

Not all phenotypic variation is due to genetic variation between individuals (learned behaviour, choice or environmental influence)

Heritability is a Ratio

variation in phenotype is V_p

variation in phenotypes due to genotype is V_g

variation in phenotype due to environment is V_e

$$V_p = V_g + V_e$$

$$\text{Heritability } H = \mathbf{V_g/V_p} = V_g/(V_g + V_e)$$

-this describes populations not individuals

Example: Height of humans. Genetic yes. Environmental – food in excess now? Earlier history? $H = 0.8$ for modern Europeans

-if food supply is equal then more importance is placed on genetics for height

NOTE:

Heritable doesn't mean Inherited

Heritable – the potential to be inherited based on environment and genotype

Heritability- phenotypic differences accounted for by genotypic differences (and environment)

Inherited – genetic info passed on (genes code for a trait)

Estimating heritability

-parent off-spring resemblance (morphology)

-limitations?

-other methods?

Recap

-selection may or may not result in evolution (must have some heritability to evolve)

-selection acts on individuals

-selection acts within 1 generation

-selection acts on the phenotype (physical or behavioural trait)

Lecture 12 – Population Genetics

Hardy-Weinberg Equilibrium

$$f(AA) = p^2$$

$$f(Aa) = 2pq$$

$$f(aa) = q^2$$

HWE

-present if population is under no evolutionary forces

-allele frequencies remain constant

-null, non evolving, reference model to help ID evolving populations

Hardy-Weinberg Principle

- very large, infinite population
- random mating only
- mutations negligible
- no immigration or emigration
- no selection
- if above met then genotype freq reflect $(p+q)^2$

HWE Implications

- if genotype frequencies are predictable from allele frequencies, then population is at HWE
- if not, population could be evolving
- dominant alleles dominate in frequency like recessive alleles do (sigmoidal top at 100%, while dominant explodes exponentially but maxes out at like 80% due to heterozygous expression of phenotype)

Allele frequency

- proportion of all gene copies of a certain variant (ie allele)

Relative Fitness = absolute fitness / absolute fitness of of fittest genotype

Terms

- population
- locus
- allele
- dominance
- genotype
- allele frequency
- genotype frequency

Dominance – whether or not an allele is expressed in a heterozygote. No relation to helpful or deleterious qualities

Some traits have both fitness advantages and disadvantages (ie reproductive vs. survival)

Selection – upsetting equilibrium

Lecture 13 – Sexual Selection

Dominance or repressiveness affects the thoroughness and rate of evolution and final outcome for an allele (frequency in population)

Dominance – is constrained by diploidy, while recessive traits may totally replace dominant ones

Pleiotropic – a single gene affecting several traits

Selection – the only source of adaptive radiation

Quantify genetic variation

- record % of heterozygous loci
- calculate inbreeding coefficients based on pedigrees
- proportion of loci that are polymorphic (have more than 1 loci)

Directional Selection

- selection against individuals at 1 extreme of a population (towards the other extreme)
- sustained directional selection usually inconsistent over long times
- inconsistent since environmental factors and favoured traits change over time typically

Stabilizing Selection

- no change in mean value of trait
- decrease in genetic and phenotypic variation
- selection favouring intermediate values of a traits, decreasing frequency of extremes

Disruptive Selection

- favours extreme values of traits
- get bimodal (dimorphic or polymorphic) distribution and stabilization
- mean trait value may also remain constant

Frequency Dependant Selection

- NEGATIVE: selection favouring rare phenotypes just because they are rare (increases variation)
- POSITIVE: selection favouring common phenotypes (decreases genetic variation)

Overdominance

- a condition in genetics where the phenotype of the heterozygote lies outside of the phenotypical range of both homozygote parents.
- can also be described as **heterozygote advantage**, wherein heterozygous individuals have a higher fitness than homozygous individuals.
- major histocompatibility complex (MHC, of the immune system)
- being heterozygous here protects from more (twice) the diseases
- supported by the sweaty t-shirt study
- balancing selection example

Things that increase genetic variation in a population:

- spatial variation in selection pressure
- overdominance
- negative frequency dependant selection

Things that decrease genetic variation in a population

- positive frequency dependant selection
- mutations

- migration
- long term directional selection (direction changes long-term?)

Lecture 14 - Evolutionary Forces (besides selection); Why Sex?

Hardy-weinberg equilibrium: no selection, no mutation, no migration/gene flow, random mating, sufficiently large (ie in order to have constant allele frequencies)

What is the benefit of sex? Why do vast majority of eukarotes have sex?

Parthenogenesis – clone of mothers of only motherhaving species. Obligate asexuals – perform courtship and pseudocopulation in order for eggs to deveop normally. Why? Weird...

Evolutionary Forces:

Mutation

random spontaneous errors in DNA
 beneficial, harmful, or neutral. Not needs directed! Just mistakes in DNA synthesis
 Effect on fitness can vary. HIV mutates AZT resistance increases fitness.
 Most mutations are neutral or deleterious wrt fitness
 Mutations produce new alleles – convert old allele to new allele
 The only source of new genetic variation
 Rare, not massive evolutionary forces.

Migration

movement of individuals in or out of populations (permanent not temporary)
 immigration or emmigration
 Equivalent to the flow of genes in or out of a population (ie where they reproduce)
 The movement of alleles between populations

Lecture 15 Why Sex?; Sexual Selection

Costs

only half of alleles put forward in any one offspring
 only females grow the population
 time investment of sex
 find a mate
 convince mate to mate with you!
 Meiosis costs (1/2 alleles passed on)

Advantages

Ruby in the Rubbish – at least one of your offspring might have good mix of alleles although many of off-spring may have lots of deleterious alleles
 environmental affects (rapid change) – produce diverse off-spring – at least some will adapt to

future environmental conditions.

Greater diversity of off-spring genotypes -Lottery Ticket Hypothesis
diversity of offspring

-Hedges bets in a quickly changing environment where a species must co-evolve with changing pests and parasites

Ecological explanation for sex:

Parasite Resistance – in a parasite/bacteria/microbial/pathogen heavy environment having a great diversity of off-spring benefits survival (at least some of off-spring will survive). Parasites apply negative frequency selection (attack most common allele types since its a better deal for them) so to thrive in that environment you should have diverse kids!

Host organisms continually evolving with their parasites – Red Queen Hypothesis

Get more males produced when risk of parasite attack is highest (lots of parasites). ie. More sexual reproduction! (not asexual)

Sex has a long-term advantages that many off-spring will die but some will live and thrive and harmful alleles (mutations) will be purged from gene pool (long evolutionary time scale)

Short term benefits:

Maybe main advantage is that you hedge your bets (on alleles) in environments that are changing often/quickly – ie change food, rainfall, temperature, predator species and parasites

Sexual Dimorphisms - often males, develop traits with no apparent survivorship advantage due to sexual selection by picky females

Intrasexual Selections – males develop weapons! Horns, tusks, antlers, etc..

Intersexual selection: make the owner of the trait more attractive to females (female choice)

Bower Bird example

males build symmetrical and elaborate bower out of grass. Add BLUE things – females likey. Females hate RED. So males put RED things on other males bowers and steal their blue stuff! So this incorporates INTERSEXUAL selection (bower building) and INTRASEXUAL selection (stealing of decorations and damaging others' bowers)

Attractive Stranger Proposition Scenario

Males accept mostly.

Females decline mostly.

Sex difference – and who invests more time to raise off-spring?

Short-term mating opportunities vs. Long-term mating opportunities

Emotional versus Physical Cheating Scenario – sex difference?

Anisogamy

Mostly males compete for females and therefore exhibit these sex differences and these extremes of sexual dimorphism (manes, plumage, building, rituals etc)

Why??? - Anisogamy

Definition: Females make few, costly, nutrient/energy rich gametes/ova while males produce lots and lots of cheap, motile, low nutrient reserve, gametes – sperm!
SPERM IS CHEAP – Bateman's principle?

Sex differences in parental investment (time, energy, resources, gestation, etc) mean the invested sex is choosy! Since they are the limiting resource of sexual partners. And the less invested sex has to COMPETE for the attention of the more invested sex.

Sexual Fitness

In humans, and all populations with **sex ratios** about 1:1 males to females; then the average fitness of males is the same as females.

However, males have a much higher **POTENTIAL FITNESS** (maximum fitness) (number of off-spring produced)

Moulay Ismael (male) of Morocco produced ~1000 children! RECORD

While Mrs. Vassilyev (female record) produced 69 children. Still a lot, but not as much at all!

Fitness = reproductive success

Strategies to maximize fitness? Male vs. Female

Male – total # of mating opportunities

Female – can't copulate with multiple males, only need one male to make sperm, they are limited by resources (time/energy to gestate, nutrients)

Males invest less than females so can afford to get it on with lots of females

Sex Role Reversal

-Thalerope birds

-Sea horses

Both due to males providing way more time/energy to raise the young and so are more choosy for mates, and therefore females compete for access to males, ie become affected more by sexual selections

Human Off-spring

Both parent invest heavily in the off-spring – some other birds do this too

So, both sexes are very choosy in the selection of LONG-TERM mating partners

Competition for access to preferred mating partners – spouses etc

But some differences come up when it comes to short-term mating

Males – not choosy

Females – still choosy

Traits important to both sexes

-symmetry

-look like you! Similarity

-but smell different! Immuno locus and such – better chance of being heterozygous for immunities and therefore resistant to more diseases

Lecture 17 – Phylogeny – Speciation

Speciation

achieving reproductive isolation

often by ALLOPATRY – geographic/physical isolation - no reproduction between 2 populations

ex: glacier separates physically two distinct habitats (or river, or highway, or other barrier)

A founder event, colonizing an island for example, would count as an allopatric barrier (the ocean separates the populations for mating with each other)

predict the populations to diverge – New species?

Genetic drift would occur typically

Speciation: isolation and divergence is sufficient

Secondary Contact:

The two populations come back into contact and we can observe the results

Islands – hotbeds of speciation

physical isolation and small populations lead to rapid genetic changes while founder effects and each island has its own selection pressures encourage speciation

Secondary Contact

What happens depends on the amount of divergence

If fairly low (similar populations) interbreed easily and form hybrid swarm

Alternately, post zygotic isolating mechanisms may have evolved and prevent interbreeding
Why? The off-spring may be sterile, have low fitness, etc

If these post-zygotic isolating mechanisms are present, then we will see the evolution of prezygotic isolating mechanisms (much less costly energy-wise)

This will prevent reproduction and time wasted gestating and or raising young with low-fitness

Reinforcement phenomena

Selection favouring prezygotic isolating mechanisms after post-zygotic isolating mechanisms have already evolved due to speciation/genetic drift between allopatric species

Lecture 19 Evolution and Ecology

Cope's Law - Vertebrates

-in general, lineages increase in body size over evolutionary time

Why? Possibilities

-selection favouring larger individuals (individual level fitness advantage)

- species level selection ex. Large bodied species less likely to go extinct and maybe more likely to speciate (make new species)

- floor effect. First living things/species were small – so can only increase in size

Exceptions to Copes Rule

-Arthropods (exoskeletons) have limits on size set by having an exoskeleton

-marine mollusks over 16 M years – many exceptions to Cope's rule

END OF EVOLUTION

Now... ECOLOGY

-Nothing in biology makes sense except in the light of evolution

- Nothing in evolutionary biology makes sense except in the light of ecology

Evolutionary Ecology

Ecology – interactions between organisms and their environment

-greek oikos – house/dwelling

Environment Components – biotic and abiotic

Biotic – interactions with other living things (same and other species)

Abiotic – interactions with non-living components (temperature, moisture, soil nutrients, etc)

Ecological Affects on Evolutionary Processes

- Speciation and extinction rates (biodiversity)

- Patterns of Selection and Evolution (micro-evolutionary processes)

Biodiversity

-a measure of the number of living forms on Earth

-measure of genetic variation in those living forms too (but we'll ignore this)

Definition – the total number of species at a certain place at a certain time

-varies over time

-there is constant turnover and replacement of species

-vast majority of every species that has ever existed has gone extinct (constant turnover)

Two competing forces affecting Biodiversity:

-extinction eliminates species

-speciation creates new species

Adaptive Radiations

-ancestral species quickly differentiating into multiple descendent species with their own distinct ecological niche (usually)

3 Main factors for AR

-Evolutionary Innovation – lineage develops new trait allowing it to thrive in new ecological niches. ex. Flowers into angiosperms better method of fertilization thru pollen (using bees etc is way more efficient than random haphazard pollination)

-Colonization Events.

Lecture 21 Population Ecology

Characteristics affect growth rate:

Age Structure

- pre, post, or reproductive age and dispersion (histogram), M and F.
- wide at base (pre-reproductive lots) then high potential for population growth
- zero growth – straight up and down proportions, narrows at older age
- wider post-reproductive – negative growth or population decline

Life table analysis

- follow a cohort of individuals
- summarize their survival and reproductive success
- categorize based on sex and age and determine mortality rate based on those

Survivorship curves

- continuum but 3 extremes are:
 - a) type 1 – large animal – only high mortality when pretty old
 - much parental care to off-spring
 - b) type 2 – constant mortality rate
 - small animals like birds
 - c) type 3 – only high mortality when young, constant low mortality when old
 - fish,

Life History Characteristics

life history – balancing energy or resources given competing demands

- growth
- reproduction
- self-maintenance

- many small off-spring?
- few larger off-spring?
- trade offs, pros and cons

Life history strategies

-characteristics of off-spring, energy use in terms of growth, reproduction characteristics, and self-maintenance.

Quantity versus Quality

r strategists (r selected species)

- high investment in reproduction
- short-maturation time
- short generation time
- high frequencies of juvenile mortality
- produce large amount of off-spring
- small body size
- invest fairly little in each off-spring
- short life span
- usually one reproductive episode
- early first reproduction
- usually large brood size

k strategists (k selected species)

- large bodied
- longer growth, maturation, generation times
- since they take more energy to growth, self-maintenance and repair
- live longer
- low mortality rate
- often extensive parental care for off-spring
- relatively stable population size
- good tolerance of environmental change
- usually several reproductive episodes
- late reproduction
- usually small clutch size

Modelling population growth

- B births
- D deaths
- I immigrations
- E emigrations (all number per unit time)
- ΔN (change in population size in unit of time)

$$\Delta N / \Delta t = B + I - D - E$$

$$b = B/N$$

$$d = D/N$$

- assume closed population

r = intrinsic growth rate

$$r = B/N - D/N = b - d$$

- the net change in population size per unit time

Exponential Growth

$$dN/dt = rN$$

- assumes r (growth rate) is independent of N (size) which is often unrealistic

Logistic Population growth
-r decreases as N increases
-as N increases, dN/dt decreases

$(K-N)/K$ = growing room factor
as N goes to K (carrying capacity) then the room to grow goes to 0

Logistic growth equation: $dN/dt = rN(K-N)/K$

Lecture 22 Community Ecology

most k selected species show logistic growth.
-what about humans? Appear to be growing exponentially so far!
-why? Still below K, carrying capacity, control environment, etc
-we have increasing N, but decreasing r

Demographic Transition Model
-human societies generally get wealthier
-preindustrial, transitional (increased economic development), industrial, post-industrial

Pre-industrial
-high r
-high d
-poor medical care

Transitional
-decrease in death rates, d
-increase in health care
-increase in wealth
-no change in r, (still large per capita birth rates)

Industrial
-move to the cities
-death rates still low
-r starts decreasing

Post-industrial
-r goes to zero
- $r < d$ even in Europe some places

Community Ecology
-interactions between different species
-defined by geographic boundaries

Why populations distributed in space the way they are?
-single critical factor (limiting) ex latitude and therefore temperature, water content, salt content, day length, oxygen content, temperature, humidity
-many species have N dimensional tolerance ranges

Tolerance Limits

- gradients of tolerance for certain factors like above
- zones of intolerance, zones of physiological stress, optimal ranges
- N dimension space of factors (temp, water, etc)

Ecological Niche Definitions

Role-based niche

- ex. Top predator

Resource based niche

- the set of conditions that an organism needs to survive (determines where it lives)
- ie sufficient temp, sufficient prey, sufficient moisture etc

Resource Niches

Fundamental Niche

- where a species can potentially live (in n-dim zone of tolerance)
- pre-interactive niche

Realized Niche

- where the species actually does live (equal or less than fundamental niche)
- post-interactive niche

Why don't species occupy their fundamental niche?

=> Competition

(Predation, herbivory, commensalism, mutualism, parasitism as well but later)

Competition Modes and Outcomes

- intra and inter specific competition
- exploitative (scramble) competition race to use resource before competitor does, indirect, no direct fighting
- interference competition – fighting directly over resources (prey items, water), don't want to eat each other necessarily

Outcomes: competitive exclusion, or resource partitioning

Outcome 1 Competitive Exclusion

- two species compete for exact same resources
- cannot coexist
- winner take all
- expansion of logistical model of a single species for multiple species
- one species logistic sigmoid shape growth, other loses and decays to zero population size
- ex: Gause's paramecia experiments
- simple environments (1 food, 1 habitat, few options)

Outcome 2 – Resource Partitioning

- multiple food and habitat resources
- species become specialized (mini-niches)
- each suffers a little bit but all coexist, none go extinct

Lecture 23 Community Ecology

Species Diversity

- composite of richness and evenness

Species Evenness

- relative abundance of each species in a community

Species Richness

- total number of species

Competition

- realized niche is different than fundamental niche typically due to competition
- ex: barnacles. Deep water barnacles out compete shallow water barnacles

Trophic Levels

- Food web or food chain
- what they eat and what eats them
- base: primary producers
- primary consumers (herbivores)
- many secondary consumers (eat the primary consumers)
- tertiary consumers etc (but rare)
- top: top carnivores

Grazing Food Web

- the producers and consumers all of which can be eaten (grazed on)
- only small portion of energy fixed by producers

Detrital Food Web

- Waste
- non-living biomass not eaten
- but broken down by decomposers (fungi, bacteria) in soil etc

Community Complexity

- how many trophic levels in the food web
- are complex communities more stable? Maybe and sometimes! Ha!

Keystone Species

- has major effects on an ecological community relative to their proportion of biomass (relative abundance)
- ex: sea otters: eat sea urchins, and prevent them from eating all the kelp forests (primary producers!). So Sea Otters are a keystone predator and essential to the kelp forest food web
- key stone species often keystone predators
- keystone predators usually increase species richness

Patterns in Species Diversity

Equilibrium Theory of Island Biogeography

- why more species on big islands than small islands?
- why more species on an island close to the mainland vs far from the mainland?

Species extinction rate and immigration rate equilibrium

- immigration rate decreases the more species are already on the island
- extinction goes up as the number of species on the island (competitive interactions?)

Big Islands have more species.. Why?

- more immigration (bigger target)
- extinction rate is lower on big islands, since it supports more ecological niches than a tiny island
- distant islands have fewer species since immigration rates are lower for farther island

Island biogeography can be applied to Habitat Islands (Nature Reserves)

Design of Nature Reserves (Parks!)

- Goal is to maintain Diversity of species (richness)
- single large area or many smaller?
- Larger is better! Less local extinction and more immigration

Ecological Succession

- change in community composition and structure over time

Primary Succession

- rocks and turns an area of no plant species to biotic environment

Secondary Succession

- soil on the ground and plants already, but community disturbed, and colonization begins again from scratch.

Pioneers.

- r selected species
- first species to arrive in a colonization
- k strategists later in succession

Climax community

- Oak forest
- once reached climax it remains steady unless disturbed

Disclimax Community (Equilibrium Communities)

- require periodic disruptions

Succession Example

- retreating glacier
- uncovers bare rock
- primary succession begins (no soil, no plants)

- lichens grow!
- produce soil, and r selected pioneer species come in
- new species keep coming in and out competing the existing species
- until we reach the climax communities (spruce forest)

What about Animal communities?

- animals undergo succession after plant life is established

Ecological Disturbance

- physical damage to a community
- removes biomass
- typically removes plant biomass (ex: large herbivore eats all the grass)
- ex: fire or flood could remove plant biomass too
- ex: Log pole pine forest require FOREST FIRES, in order for their pine cones to reseed.
- the pine cones only open up in periods of extreme heat! ie forest fires

Diversity and Disturbance

Intermediate Disturbance Hypothesis

- certain medium level of disturbance from which we expect the maximum species richness
- if too rare then diversity stagnates and only extreme K strategists live
- if disturbance is too frequent we get only r selected pioneer species

Lecture 24 Ecosystem Ecology

Ecosystems

- energy flows, nutrients cycle
- pyramids of energy, biomass, numbers
- nutrient cycles and reserves: water and carbon

Community

- different populations interacting with each other in one place (all organisms in one place)

Ecosystem

- a biotic community and its abiotic environment functioning as a system
- Open systems: require energy source (not energy cycling)
- energy (and nutrient) inputs and outputs
- energy: sun, heat, radiation, chemical
- nutrients: chemicals, organics, nutrients leaving (output)

Major ecosystem activities: Production and consumption

Production

- new biomass produced from inorganic nutrients/substances

Consumption

- biomass converted to new forms of biomass

Ecosystem – functional components

- 1) Autotrophs – producers (take CO₂ and H₂O etc and make biomass)
- 2) Consumers – heterotrophs (eats other biotic things)
- 3) Energy - solar
- 4) Nutrients

Energy Sources

- photoautotrophs – light energy
- chemoautotrophs – rely on chemical energy – where the sun don't shine
- radioactive energy

Nutrients

- chemical compounds needed for growth or reproduction
- organic or inorganic (carbon-chains – organic and CO₂ inorganic)
- micronutrients – organisms need only trace quantities (Fe, Se)
- macronutrients – organism needs a lot of (C, N, O)
- both macro and micro can be toxic in excess

Nutrient sources

- geological (mineral soil)
- atmospheric sources
- oceans
- decomposition and nutrient cycling

Energy flows up the food web

- energy goes from source to primary producers (autotrophs) through consumers (primary and secondary consumers etc) and then decomposers

Ecological inefficiency

- about 90% of energy lost going to higher trophic levels
- lost energy is constantly being replaced (ie by the sun)

Efficiency Factors

- harvesting efficiency less than perfect (carnivores on herbivores, don't catch them all)
- assimilation efficiency (not all of eaten energy gets used, not all digested)
- production efficiency – not all digested energy turns into new biomass (tissue) some or much used up by metabolic processes

Energy pyramid

- always more energy available at lower trophic levels than higher trophic levels
- ie going up: producers, (decomposers sort of lateral) herbivores, carnivores, top carnivores
- most ecosystems have 3-5 trophic levels only since each layer has inefficiencies
- pyramids of numbers too (usually) – lower number of higher trophic levels
- usually, upper trophic levels have less biomass than lower levels

Nutrient Cycles

- living and dead organisms
- ecosystems are open so nutrients can come and go
- nutrient compartments (living, non-living/dead organisms, abiotic accessible environment, or not easily available abiotic)

Generalized Compartment model

- what is currently available for assimilation?
- is it organic or inorganic?
- processes move nutrients between above compartments
- some are harder (slower) than others
- erosion of rock to available soil
- compaction of biomass into fossil fuels
- respiration

The Water Cycle

- most water is in the oceans
- fresh water only 0.003% of free water
- humans and many creatures can only use fresh water
- fresh water: groundwater, lakes, rivers, atmosphere
- atmospheric water and rain are constantly moving water about between reservoirs

Carbon Cycle

- majority is bound up in rocks (not available)
- next largest source of carbon is carbonate in ocean
- some in soil
- some in land biomass
- some in aquatic biomass?
- some in atmosphere CO₂, CH₄ etc

Carbon cycled by burning, decomposing, photosynthesis etc

We are altering nutrient cycles

- using up groundwater
- burning fossil fuels increases atmospheric Carbon
- cutting forests, decreases oxygen production and water cycling
- crop fertilization alter Nitrogen cycle

Greenhouse Effect

- greenhouse gases affect reflection of energy to space in the atmosphere
- radiation trapped in atm as heat
- human activities linked with increase of greenhouse gases
- increasing CO₂, CH₄ levels in atm over time