Earth Systems and Resources

(A) Earth Science Concepts

- Forces inside the earth (mantle convection) cause continents to drift, split and crash into each other (very slowly).

Layers of the Earth
Crust: cool, lightweight brittle rock that floats on the mantle (oceanic crust is like the mantle but has more Si while the continents are thicker, lighter regions of crust rich in Ca, Na, K, and Al).

Mantle: surrounds core, much less dense, high concentration of light elements (O2, Si, and Mg), 2,900 km in depth.
Asthenosphere: plastic-like layer of the mantle where crust rests.

Core: interior of the earth, composed of hot metal (mostly iron), solid center. Divided into 2 parts: <u>outer core</u>: semi-fluid layer. Inner Core: solid iron. 2,900-5,000 km in diameter.
Plates: large pieces of land broken and moved by huge convection currents on the upper layer of the mantle.
--Earthquakes are caused by grinding and jerking as plates slide past each other.

Three types of plate boundaries:

- <u>Convergent Plate Boundary</u>: Plates collide with one another (continent-continent or continent-ocean*) *produces volcanoes
  -When plates collide mountain ranges are pushed up.
  -"Ring of Fire" is the place where oceanic plates are subducted under the continental plates. More earthquakes and volcanoes occur here than any other place on the planet.

- <u>Divergent Plate Boundary</u>: Plates move away from one another. Generates normal faults

- <u>Transform Plate Boundary:</u> Occur as plates slide past one another

ROCKS AND MINERALS:

Mineral: a naturally occurring, inorganic solid element or compound with a definite chemical composition and a regular internal crystal structure

- **Rock:** a solid, cohesive, aggregate of one or more minerals.
  Each rock is made of grains of different minerals and the size of the grains will depend on how the rock was formed.
  Rock Cycle: creation, distraction and metamorphosis of rocks. Knowing this cycle can explain the origin and characteristics of rocks and how they are shaped, worn away, transported, deposited, and altered by geologic forces.
  Igneous Rocks: solidified from magma from the earth's interior. Magma that reaches the earth's surface cools quickly into basalt, rhyolite, andesite. These rocks have fine grains. Magma that is cooled in subsurface chambers has coarser grains and forms granite, gabbro etc.
  -Weathering: exposure to air, changing temps and chemical reactions cause the breakdown of even durable rocks. (Mechanical weathering -physical breakup of rocks into smaller particles w/o a change in chemical composition. Chemical weathering- selective removal or alteration of specific components that leads to the weakening and disintegration of rocks ex. oxidation and hydrolysis. The products of chemical weathering are very

susceptible to mechanical weathering and dissolving in water).
-Sedimentary Rock: when deposited material remains in one place long enough or covered with enough material to compact it will become this type of rock. These rocks usually have layers.
-Relatively soft sedimentary rocks can be formed into unique shapes by the wind.
-Metamorphic rocks: preexisting rocks that have been modified by heat, pressure (sediments pile on top and tectonic buckling) and chemical agents. These rocks often hold the most economically important minerals such as talc, graphite and gemstones.

Geologic Hazards

Earthquakes:
-Sudden movements in the earth's crust that occur along faults where one rock mass slides under another.
-Kobe, Japan and Mexico cities are built on soft landfills and they suffer the greatest damage from earthquakes
-Contractors plan to build heavily reinforced structures, strategically placed on weak spots in buildings, to absorb vibrations from earthquakes.
-**Tsunami**: giant seismic sea swells that can move at 1,000 km/hr or faster from the center of and earthquake.
Volcanoes:
-source of most of the earth's crust
-fertile soils are weathered volcanic materials
-Mudslide associated with volcanoes have devastated Armero and Chinchina in Columbia
-volcanic eruptions release large volumes of ash and dust into air which blocks sunlight, contributes to atmospheric cooling
-1991:Mt Pinatubo in Philipines emitted 20 million tons of sulfur dioxide producing sulfuric acid
Landslides:
-rapid downslope movement of soil or rock
-In US, $ 1 billion in property damage is done every year by landslides and related mass wasting
-threats: road construction, forest clearing, agricultural cultivation, and building on steep slopes

(B) The Atmosphere

Weather is daily atmospheric conditions, climate is long-term weather.

Initially the climate on Earth was a deadly mixture of Hydrogen, Helium and Methane from the outgassing of molten rock. 3 billion years ago oxygen was added to our atmosphere with the evolution of photosynthetic organisms.

Air composition of the Troposphere today:
Nitrogen- 78%
Oxygen- 21%
Traces of Water Vapor, Argon and Carbon dioxide

The Atmosphere has four distinct layers.
<u>Troposphere</u> (roughly 10 km up)
The layer closest to earth. Holds 75% air mass.
Gets colder with altitude
Weather happens here, also only layer with water
<u>Stratosphere</u>
The top of the stratosphere contains ozone- O3
Ozone absorbs high level UV radiation from the sun.

Temperature increases with altitude because of UV absorption
Ozone molecules are broken down by CFC (now outlawed ingredient in aerosol sprays, refrigerator coolants and electrical cleaning solvents)
Excessive UV light on the Earth causes skin cancer, cataracts and mutates and kills plankton (the ocean's bread basket).
Mesosphere
Temperature decreases with height
Thermosphere
Highly ionized gas interacts with magnetosphere to create Aurora borealis (Northern Lights)!

Global Energy Transfer- before man (and woman) global energy was in balance.
Most of the energy from the sun is in the high energy wavelengths- UV and visible light.
50% of this energy is absorbed at the surface.
Energy reflected from the surface is infrared (longer wavelengths)

The Role of the Sun (Latitude and Longitude)

- Why it rains in a rain forest: The sun's energy is concentrated near the Equator. Rising hot air expands and cools (called Adiabatic cooling). Colder air can't hold as much moisture so after a certain altitude, the air dumps out its water vapor in the form of water droplets- the stuff of clouds. Rising air creates low pressure and lots of nasty weather, unless you are a tropical plant in which case you are very happy. As the water vapor condenses it gives up latent heat energy- this helps large cloud formations rise higher, cool more and build energy to form large storm systems like hurricanes.

- Why it is dry in a desert: At 30 degrees North and South latitude the air is cooling, becoming more dense and sinking. Sinking air creates high pressure. High pressure days are cloudless, sunny days.

- Global winds are caused by the constant balancing act going on in our atmosphere as moist, warm air travels upward from the Equator and then cools and sinks at the 30 degree latitude belt. The air rises again at the 60 latitude and sinks at the poles. When the air moves laterally across the Earth's surface from belt to belt (High to Low pressure) it creates winds- we live in the Westerly wind belt which is why all of our weather comes from West to East. Below us are the trade winds which blow towards the Equator.

- All wind belts are curved to the rotation of the Earth knows as the Coriolis Effect. In the Northern hemisphere the air curves to the right. In the south it curves to the left. These curving winds are also partially responsible for the direction of the major ocean currents of the world.

(C) Global Water Resources and Use

The Coriolis effect is also what spins tornadoes and cyclones. Cyclones are low pressure centers with winds that blow inwards in a counterclockwise direction. Weather conditions are very stormy.

Milankovitch cycles-
Periodic shifts in earth's orbit (100,000 year cycle), tilt (40,000 year cycle) and axis wobble (a 26,000 year cycle). The timing of all three of these phenomenon are such that every 100,000 years or so the Earth finds itself very far from the sun- enough to trigger an ice age.

La Niña
The "normal" state of affairs with relatively cool ocean temperatures on the Equatorial Pacific Ocean. Trade winds blow

warm water in the South Pacific towards the Western Pacific Ocean. This causes a low pressure system off of Australia and Indonesia which leads to lots of rain. Nutrient rich water upwells off the coast of South America feeding a burgeoning anchovie population. In the United States we experience warm winters in the SE and cold winters in NE and the Middle Atlantic.

El Niño Southern Oscillation (ENSO)-occurs every 3-5 years. Used to last 2 weeks to a month, now lasts one month to over a year!!! Unusually warm ocean temperatures on Equator (made worse by global warming) cause the Trade winds to weaken. Warm water is sloshed back to South America. No upwelling of nutrient rich water occurs off of Peru and the anchovie population falls. Food chain disturbed.

(D) Soil and Soil Dynamics

SOIL: A Mini-Ecosystem
Mixture of weathered minerals from rocks, decaying organic material, and living organisms. About 1/2 of cropland is being destroyed quicker than replaced.

Soil Composition

1/2 mineral (from bedrock/sediments), plant & animal residue, air, water, organisms
* sandy soil: light soil, good drainage, dries quickly vs. clay (tiny particles), heavy, impermeable, holds water longer
* Humus: a sticky, brown residue from decaying plants & animals, gives structure to soil and helps drainage
Soil Biodiversity
*Topsoil contains millions of organisms, most microscopic (bacteria, algae), worms insects, animals, plant roots draw up minerals and release acids that decompose particles
*leaf litter creates new organic material

Soil Profiles

*Soil Horizons: layers of soil, reveal the history, classified by color, texture, composition,
*Horizons make up soil profiles (In order from top to bottom: O, A, E, B, C, R)
*Topsoil: **A** horizon, covered by **O** horizon (newly deposited material), minerals mixed w/ organic matter, where most plants spread their roots to absorb nutrients
*Subsoil: **E** horizon leaches soluble nutrients into **B** horizon, which is dense with clay and nutrients
*Parent Material: **C** Horizon: parent material, weathered rock, weathering allows soil to extend downward

Soil Types

Classified into soil orders by their composition (texture). Usually determined using **soil texture triangle** (diagram included on last page of this document!!)

Ways We Use & Abuse Soil

*11% of Earth is used for agriculture

Land Resources

*the average land area available to each individual is decreasing
*ways to improve usage of land: variety, better fertilizers, irrigation, pesticides, labor, water- 95% of agricultural growth
*forests, plains being converted to farmland, will eventually have to increase output/acre
*some land shouldn't be farmed (more valuable in natural state)- nutrients in the plants, not soil, would result in loss of biodiversity

Land Degradation

land destroyed by: 1) humans (buildings, etc) 2) desertification 3) erosion
*in some places, the degradation is so bad that no crops can be supported
*effects: less species, crops, biomass, diversity, vegetation, soil eroded, water runs off

Erosion: The Nature of the Problem

Importance: redistributes sediments, part of soil formation and loss, sculpts landscapes, creates silt for farming

Negatives: However, erosion can destroy topsoil, (exposing the subsoil) reduce land fertility, load rivers with sediments, smother wetlands, clog water intakes, coat reservoirs with silt

*Erosion equals a 1% loss in cropland/year

II. The Living World

Evolution

Tolerance Limits and Species Abundance

tolerance limits- the maximum and minimum levels beyond which a particular species cannot survive or is unable to reproduce, ex. temperatures, moisture levels, nutrient supply, soil and water chemistry, and living space.

-later discovered that rather than a single factor that limited growth, it was several factors working together, that determined biogeographical distribution

-for some species there may be a critical factor that determines their abundance and distribution in an area

-young animals also have more critical tolerance limits than the adults, ex. pupfish

-requirements and tolerances of species often are helpful in understanding the environmental characteristics of an area. the presence of a species can say something about the community and ecosystem

environmental indicators- species with specific tolerance limits that tell us something about the area where they are present ex. locoweeds grow in areas with a high soil concentration of selenium

Natural Selection and Adaptations

-term adapt used in two ways:

1. limited range of physiological modifications, available to individual organisms. ex. house plants left inside all winter
2. inheritance of specific genetic traits that allow a species to live in a particular environment

-natural selection acts of preexisting genetic diversity created by small random mutations and occur spontaneously in every population (please refer to study guide reference pages for diagrams of the different types of selection that lead to speciation).

-mutations slight, but in the long run, create **DIVERSITY**

-theory developed by Charles Darwin

Environmental factors that cause selective pressure and influence fertility or survivorship:

1.**Physiological stresses** due to inappropriate levels of some critical environmental factor ex. moisture, light, temp. pH, specific nutrients

2. **Predation**, including parasitism and disease

3. **Competition—**inter/intraspecific competition

selection affects individuals, but evolution and adaptation work at the population level, species evolve not individuals

*Isolation can also drive evolution, and cause for variations in species

Niche Specialization

Habitat- the place or set of environmental conditions in which a particular organism lives

Ecological niche- description of either the role played by a species in a biological community or the total set or environmental factors that determine species distribution

-Niches can evolve over time

-**Law of competitive exclusion** (competitive exclusion principle) states that no two species will occupy the same niche and compete for exactly the same resources in the same habitat for very long

resource partitioning- when competition forces one species to either migrate to a new area, become extinct, or change its behavior or physiology in ways that minimize competition
-niche specialization can cause subpopulations of a single species to diverge into separate species, but resources can only be partitioned so far

Species Interactions

Predation
predator- an organism that feeds directly upon another living organism (i.e. parasites / pathogens)
parasites- organisms that feed on a host organism or steal resources from it without killing it
pathogens-disease-causing organisms
* Predation is an important factor in evolution because predators prey most successfully on the slowest, weakest, least fit members of their target population, causing the prey species to evolve with protective or defensive adaptations to avoid predation
coevolution- the process when predators evolve mechanisms to overcome the evolved defenses of their prey

Keystone Species
keystone species- a species of group of species whose impact on its community or ecosystem is much larger and more influential than would be expected from mere abundance
-many unexpected species can be a keystone species; ex. tropical figs, microorganisms

Competition
-organisms within a community much compete for all the survival necessities: energy and matter in usable forms, space, and specific sites for life activites
intraspecific competition- competition among members of the same species
interspecific competition- competition between members of different species
-competition more of a race than a fight, animals don't want to risk getting injured
-intraspecific competition is intense because organisms are fighting directly for the exact same resources
territoriality- intense form of intraspecific competition in which organisms define an area surrounding their home site or nesting site and defend it, primarily against other members of their own species
- territoriality is helpful because it allows organisms to allocate resources by their spacing members

Symbiosis-intimate living together of members or two or more species

Mutualism- a type of symbiosis in which both members of the partnership benefit.
ex. lichens being a combination of fungus and a photosynthetic partner, alga or cyanobacterium
-mutualistic relationship may be important in evolution
Commensalism- a type of symbiosis in which one member clearly benefits and the other apparently is neither benefited nor harmed
ex. cattle and cattle egrets

Parasitism-a form of symbiosis in which one species benefits and the other is harmed.
ex. Ms. Law and tropical round worms

Defensive Mechanisms-the way that different prey adapt to either hide from or discourage predators
ex. toxic chemicals, body armor
-some organisms produce noxious odors or poisonous secretions
-plants too produce chemical compounds that make them unpalapable or dangerous to disturb

ex. poison ivy, stinging nettles
Batesian mimicry- harmless species that evolve colors, patterns, or body shapes that mimic species that are unpalpable or poisonous
Mullerian Mimicry- when two dangerous species evolve to look alike
-others use camouflage

Community Properties
-productivity, diversity, complexity, resilience, stability, and structure

Productivity-
primary productivity- rate of biomass production
-higher productivity in areas of high temperature moisture and nutrient availability

Abundance and Diversity-
abundance-expression of the total number of organisms in a biological community
diversity- measure of the number of different species, ecological niches, or genetic variation present
-as you go from the equator towards the poles, generally diversity decreases but abundance increases
-productivity is related to abundance and diversity

Complexity and Connectedness
complexity-refers to the number of species at each trophic level and the number of trophic levels in a community
-you can have an abundant community that isn't very complex

Ecological Succession-
-the process by which organisms occupy a site and gradually change environmental conditions b creating soil, shade, shelter, or increasing humidity
Primary Succession-occurs when a community begins to develop on a site previously unoccupied by living organisms
ex. island, new volcanic flow
pioneer species- in primary succession, the species that fist colonizes the new area
-often microbes, mosses and lichens
ecological development- process or environmental modification by organisms

Secondary Succession-occurs when an existing community is disrupted and a new one subsequently develops at the site
-disruption may be caused by natural catastrophe, human activity
climax community- in either primary or secondary succession, when a community develops that resists further change
equilibrium communities/disclimax communities- when landscapes never reach a stable climax in the traditional sense because they are characterized by periodic disruption
Aquatic Succession-process or succession taking place in a body or water

ECONOMIC GEOLOGY AND MINERALOGY:

-Economic Mineralogy: the study of minerals that are valuable for manufacturing and are important parts of domestic and international commerce. Metal bearing ores are the most economic minerals.

-The most valuable crystal resources are everywhere but concentrated and in places of easy access is what is needed.

Metals

-The metals consumed in greatest quantity by world industry include iron, aluminum, manganese, copper, chromium and nickel.

Nonmetal Mineral Resources

-Include gemstones, mica, talc, asbestos, sand, gravel, salts, limestone, and soils.

-Sand and gravel have the highest economic value of nonmetals and metals.

-Evaporites: are materials deposited by evaporation of chemical solutions. They are mined for halite, gypsum, and potash. Often found at 97% purity. Halite is used for water softeners and as road salt and refined as table salt.

Strategic Metals and Minerals

-World industry depends on about 80 minerals and metals, some of which exist in plentiful supplies
others do not like gold, silver and lead.

-Strategic metals and minerals: resources a country uses but cannot produce itself. A government usually will consider these materials as capable of crippling its economy or military strength if unstable global economics or politics were cut off to supplies.

-Usually less developed countries sacrifice the environment to mine and become producers of resources other countries need. This emphasis on a single export is not a stable foundation for an entire economy to be built since steady international markets are not a reality.

Environmental Effect on Research Extraction:

-Physical processes of mining and physical or chemical properties of separating minerals, metals, and other geological resources from ores or other materials.

-Ore: A rock in which valuable or useful metal occurs at a concentration high enough to make mining it economically attractive.

-Copper: concentration is close to 1 percent.

-Gold and other precious metals: concentration is close to 0.0001 percent.

Methods of Mining:

-Placer Mining: process in which native metals deposited in the gravel of streambeds are washed out hydraulically. Streambeds and aquatic life are destroyed.

-Strip mining and open-pit mining: Materials are removed from large, deep ores by big equipment.

-nearly a million acres of US land have been destroyed by strip mining

-50 percent of US coal is strip mined

-Underground tunnels- used to reach the deepest deposits.

-Mountaintop removal mining: mountain is removed from coal which devastates ecosystems.

Mining Hazards:

-tunnels collapse

-natural gas in coal mines can cause explosion

-fires produce smoke and gases

-acidic and toxic waste runoff is caused by surface waste deposits called tailings

-tailings from uranium can caused wind scattering of radioactive dust

-water dissolves metals and toxic materials which causes pollution

- Long ridges called spoil banks are susceptible to erosion and chemical weathering.

-19,000 km or rivers and streams in US are contaminated by mine drainage

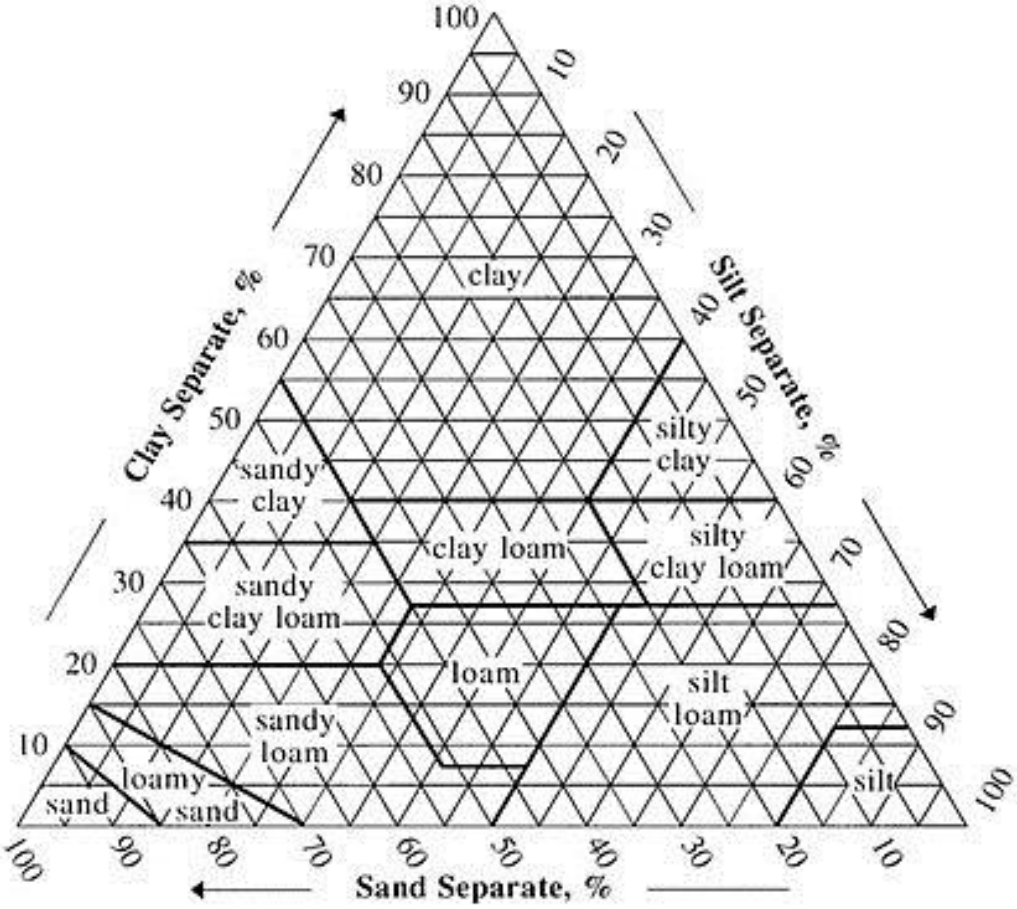
-soil is destroyed which prevents vegetation

Controlling Mining:

-1977 federal Surface Mining Control and Reclamation Act requires better restoration of strip-mined lands, especially farmlands

-expense of reclamation is high, approximately $1,000 per acre
Processing:
-Metals are released from ores by heating or treatment with chemical solvents
-Smelting: roasting ore to release metals is a major source of air pollution
-Ducktown Tennessee: mid-1800s mining companies extracted copper with huge open-air wood fires which acidified soil and poisoned vegetation
-1907: sulfur emissions from Ducktown were reduced when Supreme Court ruled to stop interstate transport of air pollution
-1930s: Tennessee Valley Authority began treating soil and replanting trees
- two-thirds are areas is now considered adequately covered
-heap-leach extraction: technique used to separate gold from low-grade ores. It has a high potential for water pollution.
-Cyanide spills have occurred in Summitville mine near Almosa, Colorado and in a gold operating mind near Baia Mare in Romania.

Conserving Geological Resources:
Recycling:
-advantages of recycling: less waste, less land lost to mining, less consumption of money, energy and water resources
-recycling aluminum consumes one-twentieth of the energy of extracting new aluminum
-1/2 of aluminum cans will be made into another can in 1 to 2 months
-platinum is recycled for used cars
commonly recycled metals are gold, silver, copper, lead, iron, and steel.
-recycled metals are used for copper pipes, lead batteries, and steel and iron auto parts.
Steel and Iron Recycling:Minimills:
-Minimills: remelt and reshape scrap iron and steel
-produce half of US steel production
-use less energy than integrated mills
-Minimills produce steel at between $225 and $480 per metric tons
-Integrated mills produce steel at $1,425 to $2250 per metric tons
Substituting New Materials for Old:
-plastic pipes have decreased our consumption of copper, lead and steel pipes
-in automobile industry, steel is being replaced by polymers (long-chain organic molecules similar to plastics) , aluminum, ceramics, and high-technology alloys
-new materials reduce vehicle weight and cost, and increase fuel efficiency
-Electronics and communication technology use glass cables to transmit light pulses instead of copper and aluminum wires



COMPARISON OF PARTICLE SIZE SCALES