**Total Fertility Rate (TFR):** Average # of babies woman has in lifetime; has declined drastically since 1950

**Trend:** Highest in developing countries, lowest in developed. **Highest:** 5+ in Africa, global was 2.8 and developed was 1.5.

**Replacement level Fertility Rate (RFR):** How many children a woman needs to have to replace her and spouse. Should be 2 but slightly higher due to infant mortality. Developed countries is 2.1; developing countries 2.5+

**Crude Birth Rate/Death Rate:** # of individuals born/dead per 1000 per year

**Demographic momentum:** Population increasing after TFR=RFR due to huge pre-reproductive and reproductive individuals.

**Density Dependent Factors:** competition, predation, parasitism

**Density Independent Factor:** weather, climate, volcanoes, fires & floods

**Age structure diagram (or population pyramid):** Two-sided histogram for males and females at different age groups. There are three general patterns for the diagrams. Age groups: Pre-reproductive age (0-14); Reproductive age (15-44); Post-reproductive (45+)

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**The Tragedy of the Commons:** We have an overpopulation problem. Ecosystems are degrading. Resources are using up. Species are going extinct. Optimal population should be about 1-2B. Author believes that people don’t have freedom to breed without limit. Government must intervene to stop population growth.

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**Calculations**

Population change = (CBR + I) - (CDR+E)

*Note: Population change is per 1000. To change to percent change, move the decimal place one place to the left.

Doubling time = 70 / Percentage Change

*Note: DO NOT change the percent to decimal. Simply drop the % sign for the calculation. This equation can be used in other contexts too.

**Keys Terms**

- Life expectancy
- Infant mortality

These both quickly let you glance at a population to determine in seconds developing or developed and potential issues the population may face.

**INDICATORS OF A POPULATION'S HEALTH**

- Need of children in workforce
- Education in women
- Importance of women in society
- Access to birth control
- Religious beliefs in birth control
- Infant mortality rate
- Age of marriage/bearing first child

**FACTORS AFFECTING BIRTH RATE**

- Availability/affordability of healthcare
- Availability of food
- Weather, volcanoes, floods
- Safe water supplies

**FACTORS AFFECTING DEATH RATE**

- Religious beliefs in birth control
- Infant mortality rate
- Age of marriage/bearing first child

**IMPORTANCE OF URBANIZATION**

- Providing family planning
- Access to birth control & abortion
- Providing education and work opportunities

**Typical Population Control Strategy**

- Incentives through rewards, tax credits, subsidies
  - Example: Russia, USA, Singapore

- Sanction through penalties
  - Example: China (losing gov subsidy)

**Education**

- Family planning, birth control, condoms

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**Phase 1**

- Pre-industrial Stage: High CBR & CDR. Population stable.

**Phase 2**

- Transitional Stage: High CBR but decreasing CDR. Rapid rise in human population. Most rapid rate of pop. increase.

**Phase 3**

- Industrial Stage: Low CDR and decreasing CBR. Pop. still growing but the growth is slower. Heading toward stabilization.

**Phase 4**

- Post-industrial stage. Low CBR & CDR. Pop. stabilized or in a decline.

**Population Control Example: China**

- One-child policy (1979-2016)
  - Two-child policy (2016-Present)
  - Significantly reduced fertility rate and increase GDP per capita.

**Problems:**

1. Aging population;
2. Increased welfare expense by gov;
3. Shrinking workforce;
4. Gender imbalance (cultural);
5. Abortion rate

**Population Control Example: India**

- Male and female sterilization (failed)
- Use of contraception (failed)
- Culture, religion, and ineffective policy implementation are the reasons for failure.
- TFR > RFR. India will become the most populous country in the near future.
**Key Facts:** Indoor air pollution is more severe and deadly than outdoor air pollution. Indoor air pollution occurs more often in rural areas where indoor burning is common. Modern buildings can also suffer from indoor air pollution as well.

**Primary pollutant:** Pollutants being discharged into the troposphere (e.g., CO₂, NOₓ, SO₂)

**Secondary pollutant:** Pollutant formed from rxn b/t primary pollutant and other chemicals (e.g., SO₃, H₂SO₄, O₃)

**Thermal inversion:** The lack of mixing/convection due to density difference (warm, lower density air already positioned on top)

**Nitrogen oxide (NOₓ):** Includes nitric oxide (NO) and nitrogen dioxide (NO₂)

**Ozone:** Stratospheric ozone is good. It helps block harmful UVA and UVB from the Sun. Tropospheric ozone is bad. It’s an irritant.

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**Primary outdoor air pollutants from fossil fuel**

- **Carbon dioxide (CO₂):** colorless & odorless
- **Carbon monoxide (CO):** HIGHLY TOXIC, colorless & odorless
- **Nitric oxide (NO):** colorless & odorless, precursor of tropospheric ozone
- **Nitrogen dioxide (NO₂):** brown fume
- **Sulfur dioxide (SO₂):** precursor of sulfuric acid (acid rain)
- **Particulate matter (PM):** Two major classes: PM2.5 & PM10; fine particles
- **Aerosols:** Chemical similar to PM in size; e.g., ammonium nitrate (NH₄NO₃)
- **Mercury (Hg):** discharged from coal burning; exists in the form of CH₃Hg
- **Lead (Pb):** formerly a major pollutant from gasoline combustion

**Primary indoor air pollutants**

- **Carbon dioxide (CO₂):** colorless & odorless; usually from cooking
- **Carbon monoxide (CO):** HIGHLY TOXIC, formed when burning w/o sufficient oxygen
- **Formaldehyde:** “new” smell from furnishings and calls
- **Radon-222:** decay product from uranium-238
- **Asbestos:** formerly used for insulation and fire prevention; fine and abrasive particles
- **Particulates:** Dusts, pollens, mites
- **Cigarette smoke:** Causes lung cancer, cardiovascular disease, unpleasant smell
- **Volatile organic compounds (VOCs):** including methane, benzene, formaldehyde

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**Key Rxns that You MUST Know**

- **Formation of tropospheric ozone (O₃) & photochemical smog**
  
  \[
  \text{NO} + \text{O}_2 \rightarrow \text{NO}_2 \\
  \text{NO}_2 + \text{UV} \rightarrow \text{NO} + \text{O} \\
  \text{O} + \text{O}_2 \rightarrow \text{O}_3
  \]

- **Formation of sulfuric acid (H₂SO₄)**
  
  \[
  \text{SO}_2 + \text{O}_2 \rightarrow \text{SO}_3 \\
  \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4
  \]

- **Formation of nitric acid (HNO₃)**
  
  \[
  \text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_3
  \]

**Solutions for photochemical smog**

- Use public transportation
- Drive hybrid/electric cars
- Bike/Walk/Carpool
- Drive more fuel efficient cars

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**Cleaner Car Exhaust: Catalytic Converter**

- **Three-way catalyst**
  
  \[
  \text{CO} + \text{NO} \rightarrow \text{CO}_2 + \text{N}_2 \\
  \text{HC} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
  \]

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**Clean Air Acts**

- **1973:** National Ambient Air Quality Standards (NAAQS) Set 6 criteria air pollutants: CO, NOₓ, SO₂, particulates, Ozone, Lead
- **1990:** (SO₂ cap and trade program)

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**Thermal Inversion**

- **Inversion Layer**
  
  Hot Air

- **Cool Air**

  E.g. Los Angeles, Las Vegas, Salt Lake City

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**Key Terms**

- **HAP:** stands for hazardous air pollutant emitted by EPA’s IRIS total

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**Electrostatic Precipitator**

- **1. Clean Coal Tech**
- **2. Wet Scrubber**
- **3. Cleaner Car Exhaust: Catalytic Converter**

- **Removes CO and hydrocarbons.**
**Topic: Water**

*Most of the water available is either saline or frozen. Estuaries and wetlands have the highest average NPP. Open ocean has the highest net NPP. Mangroves can survive in saltwater while other tree species cannot.*

**Cultural eutrophication:** Excessive supply of nutrients by humans leading to toxic algal bloom; Usually from inorganic fertilizers.

**Bioaccumulation:** The accumulation of fat soluble toxins in an individual's body.

**Biomagnification:** The amplification of toxic concentration from one trophic level to a higher trophic level.

**Dissolved oxygen (DO):** Important criterion for aquatic species survival. Pollution and toxic bloom will drastically decrease DO.

**Life zones:** Analogous to biomes in terrestrial ecosystem.

**Phytoplankton:** Microscopic plant species (producers) dwelling at the top of water surface; major contributor of DO in water.

**Zooplankton:** Microscopic herbivores or omnivores.

**Aquifer:** Group water storage; confined & unconfined; Largest: Ogallala Aquifer.

**Nektonic:** Stronger swimmers (whales, sharks, etc).

**Benthos:** Bottom dwellers (clams).

**COMMON WATER POLLUTANTS AND THEIR SOURCES**

- Nitrate (NO₃⁻) & Phosphates (PO₄³⁻): Inorganic fertilizers
- Mercury (Hg): Coal-burning power plants
- Crude Oil: Oil spill from drilling
- Mining waste: Coal mine (acidic waste) and metal mine (basic waste)
- Warm water: Heat-producing power plants (coal, gas, geothermal); Thermal Pollution
- Drugs and medications: Failure to be removed from water treatment plan
- Invasive species: Release of nonnative species; ex. Zebra mussels in Great Lakes

**Dioxins:** A result of combustion processes such as waste incineration or burning fuels. DIOXINS IS HIGHLY TOXIC! IT CAN CAUSE CANCER, IMMUNE SYS DISEASES, ETC.

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**Ecological Services**

- Climate moderation
- Nutrient cycling
- Waste treatment
- Flood control
- Groundwater recharge
- Habitats for aqua. & terr. species
- Genetic resources and biodiversity
- Scientific Information

**Water Measurements**

- Temperature
- Turbidity
- pH
- Dissolved O₂
- Nitrates
- Phosphates
- Fecal coliform
- Salinity
- CO₂

**Saltwater Life Zones**

- Estuaries
- Wetlands
- Mangrove Swamps
- Intertidal zone
- Barrier Islands
- Coral Reefs

- **Open Ocean**
  - Euphotic zone (top)
  - Bathyal zone
  - Abyssal zone (bottom)

**Freshwater Life Zones**

- **Lakes**
  - Littoral (near coast)
  - Limnetic (top & middle)
  - Profundal
  - Benthic (bottom)

- **Rivers**
  - Source zone (high)
  - Transition zone
  - Floodplain zone (near SL)

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**METHODS TO OBTAIN FRESHWATER**

- Lakes, reservoirs, aquifer & river
- Desalination (Middle East, U.S., Singapore) - Reverse osmosis or distillation

**FACTS ABOUT GROUNDWATER**

- Takes long time to recharge
- Withdrawal rate > recharge rate
- Currently considered as nonrenewable
- Also known as fossil water
- Susceptible to pollution from fertilizers, pesticides

**IMPACT OF AQUACULTURE**

- Pollution from feeds and fish species
- Use of antibiotics and hormones
- Crowded space leads to spread of disease
- Major source of fish supply from fish farms

**CLEAN WATER ACT (1972)**

- Focused on regulating discharges from traditional point source facilities (municipal sewage plants and industrial facilities), e.g. runoff from streets, construction sites, farms, etc. This act does not deal with groundwater or quantity problems.

**SAFE DRINKING WATER ACT (1974)**

- Requires EPA to regulate pollutants that will cause negative public health effects. It requires protection of drinking water and its sources such as rivers, lakes, reservoirs, springs, and groundwater wells.
**Topic: Toxicity and Waste**

“The dose makes the poison.” – Summary of classic toxicology maxim.

**LD50 (Lethal dose-50):** the dosage of a toxin it takes to kill 50% of the population

**Threshold level:** dosage level that begins to show negative effects

**Threshold toxin:** a toxin that shows a negative affect only after a certain (threshold) dosage; e.g. oxygen, water

**Non-threshold toxin:** a toxin that shows a linear direct response to toxin with dosage exposure; e.g. Lead (Pb), benzene

**Carcinogens:** chemicals that can cause cancer; e.g. Nicotine, asbestos, formaldehyde, radon-222

**Mutagens:** chemicals that leads to DNA mutations; e.g. Bromine, benzene

**Teratogens:** chemicals that cause birth defects; e.g. Mercury (Hg)

**Persistent Organic Pollutants (POPs):** powerful toxins that are known to bioaccumulate and biomagnify; e.g. DDT, DDE, PCBs, dioxins, furans

**Acute effect:** physiological effect from short exposure to high levels of toxin

**Chronic effect:** physiological effect from long-term exposure to low levels of toxin

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**Common Water Pollutants and Their Sources**

**Nitrate (NO\(_3\))** & Phosphorus (P\(_{2}\)O\(_5\)) - Inorganic fertilizers

**Mercury (Hg)** - Coal-burning power plants

**DDT** - pesticides that were used in agriculture; banned in the U.S. in 1973

**BPA** - act as an endocrine disruptor that behaves like estrogen at low doses.

**DDT, DDE, PCBs** - endocrine disruptor that affects thyroid hormones

**Crude Oil** - Oil spill from drilling

**Mining waste** - Coal mine (acidic waste) and metal mine (basic waste)

**MTBE** - Methyl tertiary-butyl ether; a stabilizing additive used for gasoline. Carcinogen.

**Warm water** - Heat-producing power plants (coal, gas, geothermal); Thermal Pollution

**Drugs and medications** - Failure to be removed from water treatment plan

**Invasive species** - Release of nonnative species; ex: Zebra mussels in Great Lakes

**Dioxins** - a result of combustion processes such as waste incineration or burning fuels

"**DIOXINS IS HIGHLY TOXIC! IT CAN CAUSE CANCER, IMMUNE SYS DISEASES, ETC.**"

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**LANDFILL (BURYING)**

55% of Trash

-Sanitary landfill (Modern) – Covered by clay and soil daily to prevent odor emission and lined with multiple layers of synthetic liner to prevent leachate contamination to surrounding environment – Built with methane & leachate collection

-Open dump (Old) – Strong odor, methane pollution, leachate contamination, pest problem

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**INCINERATION**

13% of Trash

-It is great...
  - The heat released can be used for electricity generation.
  - It takes much less space than landfill.

-It is horrible...
  - The emission from burning includes CO, particulates, toxic ash, heavy metals

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**RECYCLING**

33% of Trash

-It is effective...
  - It reduces the demand of raw materials.
  - It reduces the demand of landfill.
  - It is a sustainable use of materials.

-It is not effective...
  - Trash contamination in recyclables requires additional cost for manual removal.
  - The operating cost is still high unless there is government financial assistance.

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**Estimated Decomposition Rate**

- Paper: 2-4 Weeks
- Leaves: 1-3 Months
- Orange peel: 3-6 Months
- Milk carton: 5 Years
- Plastic bag: 10-20 Years
- Alum. Can: 200-400 Years
- Plastic Pkg Ring: 400-500 Years
- Plastic Bottle: 500+ Years
- Glass Bottle: Never

**ORIGINS OF WASTE**

75% Mining and oil/gas production;
13% Agriculture;
9.5% Industry;
1.5% Municipal;
1% Sewage sludge

**DRAWBACKS OF USING LD50**

- Data are from usually from mice testing. It may not be accurate to humans.
- Genetic difference is not being accounted for.
- Restricted to orally administered toxins
- Organisms with a larger body mass tend to have a higher tolerance. Mice may not give accurate reference to humans.

**PRIORITY OF WASTE TREATMENT**

1. Reduce, Reuse, Recycle
2. Landfill
3. Incineration (generate electricity)

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**TOXIC SUBSTANCES CONTROL ACT (1976)**

If the EPA finds any of these chemicals threatening to the environment or a human-health hazard, they can ban the chemicals from being manufactured or imported into the United States.

**STOCKHOLM CONVENTION (2001)**

In 2001, countries agreed to reduce or eliminate the production, use, and/or release of 12 key POPs. However, due to their persistence, the negative impact of POPs is still causing deaths worldwide.

**HAZARDOUS MATERIALS TRANSPORTATION ACT (1975)**

The Hazardous Materials Transportation Act of 1975 (HMTA) empowered the Secretary of Transportation to designate as hazardous material any “particular quantity or form” of a material that “may pose an unreasonable risk to health and safety or property.”
**Primary pollutant:** Pollutants being discharged into the troposphere (e.g.: CO₂, NOₓ, SO₂)

**Secondary pollutant:** Pollutant formed from rxn b/w primary pollutant and other chemicals (e.g. SO₃, H₂SO₄, O₃)

**Greenhouse gas:** Gas that can absorb heat or infrared (e.g. CO₂, CH₄)

**Acid rain:** Secondary pollutants created by SO₂ or NO₂

**Mercury:** A neurotoxin and teratogen emitted from coal-burning power plants; capable of bioaccumulation and biomagnification

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**COAL**

LARGEST RESERVES: CHINA & UNITED STATES

It is the most polluting fossil fuel, mostly used for electricity. Combustion of fossil fuel releases CO₂, SO₂ (leading to acid rain), mercury, and particulates. It is the leading cause of mercury in aquatic species. Mining of coal leads to widespread habitat destruction and pollution in air and water. Meanwhile, it is abundant with high net energy ratio.

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**OIL**

LARGEST RESERVE: SAUDI ARABIA

There are two kinds of oil: conventional (Middle East/OPEC) and unconventional (Canada/USA). Conventional Oil: Cheap, fast, and efficient to extract. Unconventional Oil: Costly and more polluting. Major risk of oil spill. Crude oil can be refined to different useful products, such as fuel, plastic, and various uses in fractional distillation method. However, it is expected to run out within 100 years.

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**GAS**

LARGEST RESERVE: RUSSIA

It is composed of primarily methane. It is difficult to transport, which makes it a less favorable fossil fuel. Natural gas is, however, much cleaner than oil and coal, producing only CO₂ and water as byproducts. Extraction method: fracking/hydraulic fracturing.

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**U-235**

EXTREMELY LONG HALF LIFE: 700K years half life

It is NOT a fossil fuel. It is considered nonrenewable because there is a finite amount of uranium-235 on earth. It does not emit CO₂ during the electricity generation process but it requires extensive energy for mining. WE DO NOT HAVE A LONG TERM SOLUTION FOR NUCLEAR WASTE.

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**HYDRO**

POLLYING BEHIND THE SCENES

No CO₂ emission during electricity generation. But proved to be a major CO₂ and CH₄ emission source from decomposition in upstream areas. It leads to displacement of people upstream of the reservoir and disruption of aquatic ecosystems in the downstream. Some Rxns like algae bloom are not always a bad thing. China has the most dams and the most generation capacity from hydropower. Some dams are built in seismic zones, such as the Three Gorges Dam (China).

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**WIND**

ONSHORE VS. OFFSHORE?

The cleanest and most popular renewable energy. It could lead to noise pollution but they are usually located away from urban areas. Onshore wind turbines are cheaper but the wind speed limits its production capacity. Minimum wind speed for wind turbines to operate is 15 mph. Offshore wind turbines would offer much better capacity due to higher wind speed but they cost too much to build since they require long, water-resistant electricity transmission lines.

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**SOLAR**

ACTIVE SOLAR & PASSIVE SOLAR

Active solar power includes photovoltaic cells (PVs) and steam-generating power plant. The two major problems are (1) they require a huge amount of land and (2) manufacturing of the PV panels requires mining of rare earth metal. (Consider all the negative impacts on ecosystem from mining.) Passive solar uses the design on the building to reduce the use of energy to keep house warm in winter and cool in summer. Houses should face south (generally) to receive more sunlight in winter.

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**BIOMASS**

BURNING VEGETATIONS (e.g. TREES)

Biomass is considered as renewable energy sources because the vegetation absorbs CO₂ from photosynthesis and the same amount of carbon is being emitted during burning. Therefore, the net carbon emission is considered as zero. However, burning biomass poses significant health issues because the regions where biomass is used are likely poor and indoor air pollution from burning will be a leading factor of death.

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**FUEL CELL**

HYDROGEN; POOR NET ENERGY RATIO

Fuel cell is still at an experimental stage because the net energy ratio is less than 1, meaning that there is a net energy loss to use such energy. Hydrogen is difficult to extract and it is not abundant (0.0000056%) in the atmosphere. The advantage of fuel cell is that the only byproduct (or "waste") is water vapor. It is a GHG with a very short residence time in the atmosphere when compared to CO₂. The risk of fuel cell includes safety of the storage device due to explosion risk.

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**TIDAL/WAVE**

SMALL PRODUCTION CAPACITY

Tidal/Wave energy harnesses the constant motion of water in the ocean. It does not alter land use and only has a minimal impact on the shallow seafloor. The limitation of this energy source is that the scale of energy production is small. It won’t be able to compete with wind or solar. It could be used to provide electricity in remote areas but not larger cities or substantial.

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**GEOTHERMAL**

ONLY AVAILABLE IN SEIZME ZONES

Geothermal power plants can be built at seismic zones where energy from magma can be used to heat water to produce steam. Because of its location, earthquake could pose significant risks to the structure of the power plant. In addition, geothermal energy could lead to water pollution that contaminates groundwater. The U.S. is currently leading the country in geothermal electricity generation.

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**ETHANOL**

IT DEPENDS ON THE SOURCE CROP.

There are different crops used to extract ethanol. In the U.S. corn is used for ethanol extraction while Brazil uses sugarcane and switchgrass. Corn-based ethanol has a poor net energy ratio, slightly above 1, whereas sugarcane- and switchgrass-based ethanol has a net energy ratio of 5-8. The problems of using corn as fuel source are (1) It requires the use of fertilizers and pesticides; (2) Corn is a significant food source; (3) There are not many vehicles that can utilize ethanol as fuel.

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**CLEAN AIR ACTS**

1973: National Ambient Air Quality Standards
NAAQS Set 6 criteria air pollutants: CO, NOₓ, SO₂, particulates, Ozone, Lead

1990 (SO₂ cap and trade program)

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**WHAT YOU MUST KNOW...**

- The pros and cons for each energy sources
- Environmental damages from nonrenewable energy
- Grades of coal (lignite, subbituminous, bituminous, anthracite)
- The ecological damages from ANWR oil drilling
- China is the leading country in wind power and hydropower in production.
- China and the US. have the most coal, CO₂ emission from fossil fuel combustion.
- The structure of nuclear power plant
- The generic structure and parts of steam-powered power plants
- Limitation of each renewable energy source
- The separation of products from crude oil through fractional distillation
- Half life definition and calculation from nuclear isotopes
- Calculations w/ energy units (BTU, kcal, Joules, etc.)
- Energy efficiency calculations
**Topic:** CLIMATE CHANGE

**Key Facts:** Climate change is caused by anthropogenic emission of CO₂. Temperature has been steadily increasing. The rising CO₂ concentration and temperature is causing various disasters.

### PRIMARY IMPACT FROM CO₂ INCREASE

#### RISE IN GLOBAL AVERAGE TEMPERATURE
Because CO₂ is a GHG, it absorbs thermal radiation (infrared) and makes the climate warmer. With removal of trees, we are putting more CO₂ in the atmosphere.

#### ACIDIFICATION OF OCEAN
With more CO₂ in the atmosphere, it disrupts the balance between ocean and CO₂. More CO₂ will dissolve into the ocean, forming carbonic acid (H₂CO₃), making the ocean more acidic.

### SECONDARY IMPACT FROM CO₂ INCREASE

#### MELTING ICE EVERYWHERE
Ice sheets from Greenland and Antarctic have been melting at unprecedented rate in the previous decades. Ice extent at the Arctic continues to shrink over the years. It will affect the thermohaline circulation, which redistribute heat. **WITH LESS ICE ON SURFACE, MORE HEAT WILL BE ABSORBED BY LAND OR WATER, CAUSING FURTHER HEATING.**

#### EXTREME WEATHER EVENTS
These events include droughts, precipitations (rain or snow), tornadoes, hurricanes, and heat waves. According to IPCC, the U.S. will have more severe drought. India with stronger monsoon. The intensity of hurricane will increase (not the number of hurricanes).

#### SEA LEVEL RISING
Two causes of increasing ocean volume: (1) More ice melt (freshwater) from glaciers and ice sheets; (2) Expansion of sea water from warmer ocean. Rising sea level will jeopardize coastal ecosystems, countries, and cities that are near or below sea levels.

#### INCREASE IN METHANE (CH₄) EMISSION
Lots of CH₄ stored under permafrost at deep ocean due to decomposition. When melting permafrost and warmer ocean, CH₄ is released into the atmosphere. **CH₄ is a GHG and it is 30x more powerful in absorbing heat compared to CO₂.**

#### CORAL REEF BLEACHING & DYING
Corals rely on microorganisms and algae to provide nutrients for them to grow. With the stress from warmer and more acidic ocean, the microbes are dying fast. It leads to the discoloration (bleaching) of corals, which will eventually lead to the death of corals.

#### DISRUPTING SEASONAL PATTERNS
Winter becomes shorter. Spring comes earlier. Summer gets longer. We notice the change of seasonal patterns by observing indicator species such as migratory birds and trees that lose their leaves for winter. This will cause major impact of the balance of food chain and species population.

#### INVASIVE SPECIES, VECTORS, DISEASES
Warmer temperature will put stresses on native, endemic species that have a narrow range of tolerance. More adaptive invasive species could threaten the population of native species. Population of vectors, such as mosquitoes and ticks, will increase exponentially (r-species). This will help diseases like Lyme disease, malaria, West Nile Virus.

#### WILDFIRE: FREQUENCY AND INTENSITY
With more drought and higher temperature, more forest trees and species are expected to removed from wildfires. In the U.S. there are more intense wildfires in California, Colorado, Washington State in the past yrs.

### KEELING CURVE
![Atmospheric CO₂ at Mauna Loa Observatory](Atmospheric CO₂ at Mauna Loa Observatory)

**2019/04 CO₂ READING: 413 ppm**

### ULTIMATE CAUSE OF CLIMATE CHANGE

CO₂ from fossil fuel burning

**THERE IS A BUILD-IN DELAY ON EVENTS.**

It is important to understand that there is a build-in delay on climate change and also sea level rise. It may take years to see the full impact of increasing CO₂ concentration and temperature.

### MONTREAL PROTOCOL (1987)

Int’l agreement that phased out the production of CFCs and HCFCs. Both will cause the depletion of ozone.

### KYOTO PROTOCOL (1997)

Int’l agreement that aimed to cut down GHGs/carbon emission. Nations set target for GHGs reduction such as: CO₂, CH₄, N₂O, SF₆, HFCs and PFCs. Major countries who did not sign the agreement: U.S.A. and Canada (withdrawn in 2006).

### PARIS CLIMATE ACCORD (2016)

The Accord aims to respond to the global climate change threat by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Despite President Trump’s opinion against the Accord, the earliest withdrawal date is Nov 2020.
WEATHER PATTERNS

CLIMATE: Climate is a pattern of weather conditions at a specific region. Climate data is produced by averaging at least 30 years of weather data, such as temperature and precipitation. We can also study ancient climate by studying ice core and tree rings. Ice core samples reveal ancient GHG levels and temperature, usually done by studying element isotopes, such as oxygen.

DESERTS: Minimal annual rainfall
- Tropical Desert
- Temperate Desert
- Cold Desert

FORESTS: Plenty of rainfall
- Tropical Rainforest
- Temperate Deciduous Forest
- Boreal, Coniferous Forest

GRASSLANDS: Moderate rainfall depends on the seasons
- Tropical Grassland (Savanna)
- Temperate Grassland
- Arctic Tundra

CHAPARRAL: FIRE RISK
- Dry annual cycles with high temperature increase fire risk

These cells (Hadley, Ferrel, Polar cells) create winds called TRADE WINDS as the air rises and sinks. In the Northern Hemisphere, warm air around the equator rises and flows north toward the pole. As the air moves away from the equator, the Coriolis effect deflects it toward the right. The air cools and descends near 30° N/S latitude. The descending air blows from the northeast to the southwest, back toward the equator.

Northern Hemisphere

THERMALINE CIRCULATION: A global ocean circulation that transports heat across all the major oceans. The warm water descends near Greenland as water evaporates near Greenland, resulting in denser saltwater. The melting of Greenland ice sheet would dilute the saltwater, reducing the rate of sinking. This will slow the entire circulation, creating areas in Indian Ocean and Pacific Ocean (near Japan) to accumulate heat. This would breed powerful storms and monsoon that could jeopardize human lives in the affected regions.

Upwelling causing significant temperature difference by the coast. This feature can be seen near the San Francisco Bay area where the wind often pushes the surface water offshore, causing upwelling. This is why Alcatraz was built at San Francisco because the water would be too cold for prisoners to escape.

Rain Shadow Effect: Windward side of the mountain acts as barrier, forcing the moisture to condense. The windward side will have more precipitation. As the air passes through the mountain range without the moisture, the leeward side of the mountain is dry, possibly having a desert climate. Example: Arizona, Nevada, Chile

THE EL NIÑO PHENOMENON

Normally, the winds flow from East to West, and push the warm sun heated surface water from East Pacific over to West Pacific near the equator. Every few years the trade winds in the tropics weaken or sometimes reverse direction. When this happens it is called an El Niño pattern.

IMPACT OF EL NIÑO

During an El Niño pattern, the winds weaken or reverse, so warm water is pushed towards the South & North American western coasts (instead of away) and causes the surface water to heat up there. Since wind isn’t pushing the warm water away, El Niño suppresses upwellings, resulting in less food for predators AND fisherman too. In terms of weather pattern, due to higher sea surface temperature, the evaporation rate of water increases, leading to more rainfall in the U.S. (west coast & Midwest).

La Niña is the EXACT opposite of El Niño. The Pacific experiences unusually cool surface water temperatures along the California coast as the trade winds speed up, which makes for larger than usual upwellings along the coasts of California and South America. Hurricane activity in the Pacific declines these years. Because of La Niña, Texas, California, Arizona, and New Mexico experience a “Mega-drought” between 2009 and 2012.

COLD FRONT: Thunderstorm due to rigorous convection, heavy rainfall, sudden drop of temperature after the passing of a cold front

WARM FRONT: Light rain/drizzle; cloudy sky
**Topic:** GEOLGY/MINING

**Key Facts:** Mining involves the exploration and extraction of nonrenewable materials. Mining activities can pollute air and water and requires use of fossil fuel.

**Subduction:** A denser tectonic plate is subsumed underneath another less-dense tectonic plate. Earthquakes can occur.

**Hot spot:** Hot magma intrudes through the crust, forming volcanic islands. Example: Hawaii & Yellowstone volcano.

**Igneous rock:** Rocks formed by lava (on earth's surface) or magma (below earth's surface).

**Sedimentary rock:** Rocks formed by weathering and/or erosion (by wind, water, and/or acid) of igneous or metamorphic rocks.

**Metamorphic rock:** Rocks formed by heat and pressure below the earth's surface. Usually found near convergent plate boundary.

**Richter Scale:** A logarithmic scale that describes the magnitude of an earthquake event. Ex. M 8.0 is 10x stronger than M 7.0 and 100x stronger than M 6.0. In terms of energy released in an earthquake event, each integer difference 30x. M 8.0 earthquake releases 30x more energy than M 7.0 and 900x more energy than M 9.0. Earthquake with M 6.0 or higher is considered as an major earthquake.

**Focus:** Location of an earthquake. Shallow earthquake is <70 km from the surface; deep earthquake is >300 km below surface.

**Epicenter:** The surface perpendicular above the focus.

**Tsunami:** Gigantic ocean waves caused by the displacement of water. Recent events: 2011 Tohoku (Japan), 2004 Sumatra (Indonesia)

**Spoils:** Waste soil and rock removed during surface mining. **Gangue:** undesired, waste materials in an ore.

**Tailings:** Leftover, useless materials from mining; usually mixed with waste water.

**MINING METHODS**

- Open-pit mining: Cheapest and safest mining method. It devastates large area of land by removing trees and natural habitats.
- Strip mining: More eco-friendly but costly because smaller area of land is being mined.
- Contour mining: More eco-friendly but costly. Mining is done along the same height of a mountain.
- Mountaintop Removal: Devastating to natural habitat and ecosystem, especially when mountains have great biodiversity due to the diversity of climate and ecosystems. Example: West Virginia

**THE GENERAL MINING LAW OF 1872**

Outdated mining law to let mining company to buy land at a cheap price to develop the West. It becomes a loophole to acquire valuable land cheap.

**SURFACE MINING CONTROL AND RECLAMATION ACT (SMCRA)**

This was passed in 1977 due to mining occurring without the disregard of the environment. This program paid for the cleaning of abandoned mines to help the environment. SMCRA requires that companies obtains permits, gives government authority to regulate and inspect mining sites, and prohibits mining on certain lands such as national parks.

**CERCLA (1980), also known as Superfund, established prohibitions and requirements concerning closed and abandoned hazardous waste sites; provided for liability of persons responsible for releases of hazardous waste at these sites; and established a trust fund to provide for cleanup when no responsible party could be identified. It has two response actions: Short-term removals (urgent) and Long-term remedial response actions (not immediately life threatening).**

**RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)**

RCRA (1976) is created by the EPA to (1) manage and regulate solid waste; (2) manage and regulate hazardous waste; and (3) protect groundwater from underground storage tanks (such as nuclear waste storage facilities). It also aims to reduce over amount of solid and hazardous waste.
**Organic fertilizer**: Made from compost and/or cow manure. Nutrients can slowly release to soil for plant absorption.

**Inorganic fertilizer**: Made from chemicals that can easily dissolve in water. Nutrients not absorbed by plants can pollute water.

**1st Green revolution**: Industrialization of farming practice by utilizing heavy machineries. Increases the use of fossil fuel.

**2nd Green revolution**: Innovation of genetic engineering that can modify crops to be resistant to drought, flooding, diseases, etc.

**Traditional subsistence farming**: Small scale farming in rural areas that aims to provide crops for farming to be self-sufficient.

**Traditional intensive farming**: Moderate scale farming that aims to provide crops for farmers to sell for small profit.

**Soil erosion**: Loss of topsoil and nutrients by exposure of soil to sunlight/water/wind. Decreased crop production or crop failure.

**No-till farming**: Conservation farming practice that reduces the disruption of top soil. Covered by dead organic matter to protect soil.

**Soil salinization**: Accumulation of minerals/salts from excessive irrigation.

**Feedlot**: A.k.a. Concentrated animal feeding operation (CAFO); Un sustainable practice of livestock farming. It requires intensive use of fossil fuel, water, and, sometimes, hormones and antibiotics. It leads to major water pollution problem from surface runoff.

**Aquaculture**: As global fish stock collapses, more fish are farmed from cages in the water to provide sufficient supply for global market. It causes water pollution problems as feeds, feces, pollutants, and diseases easily spread in the water.

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**SUMMARY OF PESTICIDES**

**First-generation pesticides**: Highly toxic compounds such as arsenic, mercury, and lead that cannot be broken down because they are elements.

**Second-generation pesticides**: Synthetic organic compounds such as DDT. It is harmful because (1) it is a broad spectrum pesticide, meaning that it is toxic to a wide range of pests; (2) It is persistent, i.e., it does not breakdown in long time; (3) It is fat-soluble, i.e., it can bioaccumulate and biomagnify.

**Monsanto, GMOs & glyphosate**: Monsanto developed and modified soybean seeds that can resist the application of glyphosate (key ingredient in Roundup®). It dominates the soybean market. Frequent, repeated usage of glyphosate (or any pesticides) will lead to chemical and genetic resistance, causing the rise of superweed. Glyphosate is proven to be carcinogenic and Monsanto is ordered to pay millions of compensations to the victims.

**Rachel Carson**: A biologist who wrote the book Silent Spring to raise public awareness on the uncontrolled use of pesticide that led to the death of fish and birds.

**Chemical treadmill**: Farmers who have been using pesticides to treat pests is forced to use more pesticides or more powerful pesticides in order to suppress pest problems. It’s a financial problem too.

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**INTEGRATED PEST MANAGEMENT (IPM)**

**Physical Control**: Highly toxic compounds such as arsenic, mercury, and lead that cannot be broken down because they are elements.

**Biological Control**: Synthetic organic compounds such as DDT. It is harmful because (1) It is a broad spectrum pesticide, meaning that it is toxic to a wide range of pests; (2) It is persistent, i.e., does not breakdown in long time; (3) It is fat-soluble, i.e., it can bioaccumulate and biomagnify.

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**WATER IRRIGATION METHODS**

**Drip irrigation**: Directly deliver water to plant roots and/or soil surface to reduce evaporation. It can reduce water usage by 80% and increase crop yields.

**Drought-tolerant crops**: This kind of crop can reduce the consumption of water.

**Irrigation scheduling**: Integrating water sensors and weather forecast to determine the amount of and times to irrigate can reduce overconsumption of water.

**Windbreaks**: Planting 1 to 2 stands of trees around a farm can reduce evaporation rate and soil erosion by wind.

**Conservation tillage or no-till farming**: Using minimal to no-till practice can increase soil’s ability to retain moisture. Cover crops can reduce exposure to sunlight and wind and, thus, reducing loss of water from evaporation.

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**CASE STUDY: HONEY BEES**

**Bottom trawling**: Fishing boat dragging large fishing nets near the bottom of the ocean floor. It results in large fish catch and also bycatch. It severely destroys the habitats of the ocean floor, including corals.

**Longlining**: A single long line with hooks that may result in large number of bycatch. The line and hooks can get stuck by rocks or corals, becoming harmful trash.

**Purse seine**: Fishing boat captures a small area of fish by circulating the fish with nets and then pulling all the fish out of water. Relatively smaller amount of bycatch.

**Gillnetting**: Stationary net with hooks that would capture the fish. Because the net is often invisible by fish, the hooked fish at the net may attract other fish to swim to the net, increasing fishery yield.

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**COMMERCIAL FISHING METHODS**

**NO₃⁻** Nitrates

**PO₄³⁻** Phosphates

**SO₄²⁻** Sulfates

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**A NATION DEPENDENT ON CORN**

The United States is known for corn farming in the High Plains. The area is suitable for corn farming because of the climate and the abundance of groundwater from the Ogallala Aquifer, which results in drastic depletion of the Aquifer. Corn farmers are subsidized by the government. This allows corns to be sold at a price below cost. This is the reason that corn is used to make animal feeds for livestock, which allows the meat price to be cheap. Fast food restaurants can sell meat products cheap for this reason. In additional, corn is used for the extraction of ethanol, despite the energy yield ratio is barely over 1.

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**FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)**

Focused on providing federal control of pesticide distribution, sale, and use. EPA was given authority to study the consequences of pesticides usage and require users to register pesticides purchases.

**MACRONUTRIENTS -- LARGE QUANTITY**

- Vitamin A (blindness)
- Vitamin D (Rickets)
- Calcium (bone loss)
- Iron (anemia)
- Iodine (goiter)

**MICRONUTRIENTS -- SMALL QUANTITY**

- Vitamin C (Scurvy)
- Lysine

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**Honey bee population is collapsing worldwide. This phenomenon is known as Colony Collapse Disorder (CCD). There are a few reasons that lead to CCD.**

**Pesticide/Neonicotinoid**: It is a known pesticide that will attack honey bees’ neurological system, causing honey bees to lose their ability to navigate back to their beehives. It has already been banned in the European Union. The US, however, still allows the use of neonicotinoid.

**Parasite/Varroa Mite**: This mite spreads globally due to the global pollination operation. Honey bees are shipped to different continents to pollinate crops. Varroa mite can live inside the bee’s body and eventually kill the bees. Use of chemicals to eradicate the mites is not an ideal option because it may lead to chemical resistance by the mite. Co-evolution would be a better strategy to let bees to fight off the mites.

**GMOS**: The change of genetics in crops is affecting the chemistry of honey bees’ diet.

**Invasive species/Zombie fly**: Zombie fly is a natural predator of fire ants. It is introduced as the biological control of the fire ants in the US. It is known that the fly can attack honey bees as it does to fire ants. It highlights the challenge of biological control on invasive species.
**Native species:** Species that have established stable population dynamics in the habitat.

**Nonnative species:** Migrated species in new habitats. May not survive if they fail to adapt or become invasive with no predator.

**Invasive species:** Exist without the presence of natural predator. Population size explodes and invade native species’ niche.

**Indicator species:** Capable of revealing important information about the environment, such as air/water quality, e.g., birds, fish

**Foundation species:** Help establish living habitat for other species. e.g., elephants, corals

**Keystone species:** Exist in small quantity but have significant impact on the health of an ecosystem, primarily population control.

**Endemic species:** Specialist species that are found in a unique habitat. Small population. Extremely sensitive to habitat changes.

**Generalist:** Adapt to wide range of living conditions. High tolerance on temperature, moisture, pH, etc. Likely to be invasive species.

**Specialist:** Adapt to specific breeding conditions. Unable to survive when conditions are changed. Likely to be threatened/endangered.

**Endangered species:** High chance of species extinction if no actions or done to protect the species.

**Threatened species:** Shows a sign of population decline. Could become endangered if no protective actions are done.

**K-species:** Few offspring, low reproductive rate, late reproduction, parental care, larger body size, die late. Logistic population growth.

**r-species:** High reproductive rate, lots of offspring, smaller body size, early reproduction, die early. Exponential population growth.

**Carrying capacity (K):** The maximum population allowed by the available resources at the habitat. It may vary due to condition changes.

**Intrinsic rate of increase:** The maximum rate of population increase under ideal conditions: plenty of food and mating partners.

**Biotic potential:** The maximum population size under ideal conditions with the maximum rate of population increase.

**Overshoot:** Overpopulation of a species when it exceeds the carrying capacity of the habitat.

**Reproductive time lag:** The time between overshoot and population collapse after population exceeds carrying capacity.

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**ENVIRONMENTAL FACTORS**

**MASS EXTINCTIONS**

Mass extinction occurs when the extinction rate exceeds the natural background extinction rate. There were five (S) mass extinctions in the past, most driven by climate change due to unexpected events such as meteor strike.

**Sixth Mass Extinction:** Current extinction rate is at least 100-1000X greater than background extinction rate. This mass extinction is driven by human beings due to climate change.

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**SURVIVORSHIP TYPES**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Most individuals can survive through the early stage and mature. Late deaths.</td>
</tr>
<tr>
<td>II</td>
<td>Some individuals cannot survive through early and developmental stages.</td>
</tr>
<tr>
<td>III</td>
<td>Most individuals may not survive through early and developmental stages. Early deaths.</td>
</tr>
</tbody>
</table>

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**PROBLEM W/ SMALL POPULATIONS**

**Founder Effect:** Limited individuals in a new colony. The number of healthy offspring could be limited due to the lack of genetic diversity.

**Genetic Drift:** With small population, the chance of unique genetic traits could be driven out of the gene pool due to limited mates.

**Demographic bottleneck:** Occurs after catastrophes (natural or human made). Low population size that may not reach the minimum viable population size could go extinct.

**Inbreeding:** High risk of genetic diseases when close relatives are mating to produce offspring. Healthy offspring will be limited.

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**FOREST PARTS**

- **Emergent layer:** Few tree crowns that surpasses the canopy layer. **Canopy:** Majority of tree grown. **Understory:** Below canopy.
**Key Facts:** Some diseases can be prevented by making better decisions to avoid risk factors such as drug use, alcohol abuse, unsafe sex, overeating, smoking, and exposure to harmful chemicals. Genetics can play a huge role on human health too.

**Pathogens:** viruses, bacteria, fungi, protozoa, parasitic worms

**Patient Zero:** The first patient who is known to contract a certain disease. All individual contacted Patient Zero must be diagnosed.

**Emergent disease:** Diseases that are new or have existed previously with a rapid increasing trend in incidence and/or area.

**Epidemic:** Disease that is affecting a localized region. **Pandemic:** Disease that is affecting global regions.

**Vaccines:** Dead or weakened virus or bacteria that can allow human body to create immunity from some diseases.

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**TRANSMISSIBLE DISEASES**

**SEVERE ACUTE RESPIRATORY SYNDROME (SARS)**
SARS is a viral respiratory illness that was first reported in 2003. It spreaded rapid in Asian countries, killing hundreds of people in China, Hong Kong, and some in Canada. Global travel makes the spread easier.

**INFLUENZA (FLU)**
Major seasonal viral disease that can be transmitted for air and exchange of body fluid. The virus changes every year. Flu can be prevent by vaccines. It could potentially become pandemic as in Spanish Flu in 1918.

**TUBERCULOSIS (TB)**
TB is a bacterial disease. It affects lungs and possibly other parts of the body. It can spread through air through coughs, sneezes. AIDS patients can die from TB easily.

**HEPATITIS-B**
Hepatitis-B can be transmitted through sex, needles, and birth from mother. There is no cure for this disease. Newborn babies can be vaccinated to prevent contraction of Hepatitis-B.

**HEPATITIS-C**
Hepatitis-C can be transmitted through sex, needles, and birth from mother. There is no cure for this disease. Newborn babies can be vaccinated to prevent contraction of Hepatitis-C.

**EBOLA**
There is no known cure or vaccine to Ebola. It has extremely high death rate and it can be transmitted easily by close contact. Countries affected: Guinea, Liberia, Sierra Leone, Congo (all in Africa).

**HIV/AIDS**
HIV can be transmitted through sex, shared needles, and birth. Infants with HIV have short lifespan (< 40 yrs). HIV has long incubation time and eventually attack and destroy the patient's immune system, causing AIDS.

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**OTHER DISEASES**

**MOSQUITO-RELATED DISEASES**
These diseases include malaria, dengue fever, West Nile virus, Zika virus. Mosquitoes are known vectors to spread these diseases. Eliminate standing water to suppress mosquito population.

**ASTHMA**
Asthma is known to affect infants, children, and elders in areas where pollution is a major environmental problem. It does not transmit to other people.

**OBESITY-RELATED DISEASES**
Diabetes, cardiovascular diseases, and certain types of cancers, including colon cancer, breast cancer. The U.S. and Mexico are the top two obese countries in the world. These diseases put heavy burden to the medical system.

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**DEADLIEST DISEASES IN THE USA**
1. Heart Disease
2. Cancer
3. Unintentional injuries
4. Chronic lower respiratory diseases
5. Stroke
6. Alzheimer disease
7. Diabetes
8. Flu & Pneumonia
9. Kidney disease
10. Suicide

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**Topic:** WILDFIRES

**Key Facts:** Most wildfires are caused by humans. Climate change will increase the occurrence of large scale wildfire because of drought.

**Prescribed fire:** Controlled burn to remove excess fuel on forest floor and control pest population near the trees.

**Surface fire:** Only the leave litter and some dead plants are burned. Small scale and easy to put out.

**Ground fire:** More extensive than surface fire. Harder to put out because the moisture level is low, often during drought.

**Crown fire:** Tree crowns in the canopy layer is burnt. Due to convection of air, it can spread very quickly.

**Leave litter:** It is a fuel for wildfire. It needs to be eliminated by prescribed fire during late winter or early spring season.

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**Mechanism of Crown Fire**
Oxygen-poor air rises, creating an updraft of air that drives the convection of air at the scene.

Oxygen-rich air is sucked into the burning site due to convection.

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**OUR UNDERSTANDING OF WILDFIRE**

**EARLY STAGE:** Before the full understanding of wildfire, it was thought that any wildfire is bad for the environment. It led to a period of wildfire suppression. This resulted in more intense wildfire that puzzled scientists.

**DISCOVERY:** It was later discovered that fire is essential for some tree species. They rely on fire to eliminate weeds and pests that would harm the trees’ survival. Some tree species have developed adaptations for occasional fires. Some seeds can only germinate after moderate burn near the ground.

Wildfire can be difficult to control and put out when there are too many leave litters remained on the forest floor. This is why we established prescribed fire to reduce fuel for wildfire.

**Slogan:** "ONLY YOU CAN PREVENT WILDFIRE."