Hazards

- West coast: Earthquakes, landslides
- East coast: hurricanes
- Mid-continent: Tornadoes, blizzards
- All areas: Droughts
- Droughts are time periods when there is very little precipitation
- Some hazards pose a risk to both humans and the environment
    - Nuclear meltdowns
    - Toxic gas release
    - Oil spills
    - Ozone depletion
    - Acid rain
    - Infrastructure failure
    - Shipwrecks
    - Airplane crashes

Processes and Natural Hazards

- Natural hazards can arise from 3 main processes:
    - Internal forces within the Earth → Driven by the internal energy of the Earth
      Ex. Plate tectonics
    - External forces on Earth's surface → Driven by the Sun's energy
      Ex. Atmospheric effects
    - Gravitational attraction → Driven by the force of gravity
      Ex. Downslope movement

Definitions

- Hazard → A process that poses a potential threat to people or the environment
- Risk → The probability of an event occurring multiplied by the impact on people or the environment
- Disaster → A brief event that causes great damage or loss of life
- Catastrophe → Massive disaster

Examples of Recent Catastrophes

- Tsunami – Thailand, 2004
- Hurricane (Katrina) – New Orleans, 2005
- Earthquake – Haiti, 2010
- Oil Spill – Gulf of Mexico, 2010
- Tsunami – Japan, 2011

Hazards as Potential Catastrophes

- More likely to be catastrophic:
    - Tsunami, earthquakes, volcanoes, hurricanes, floods
- Less likely to be catastrophic:
    - Landslides, avalanches, wildfires, tornadoes

Magnitude and Frequency

- The impact of a hazard is a function of both its magnitude (i.e. energy released) and frequency
- It can also be affected by other factors (geology, land use, population density, etc.)
- Magnitude-Frequency Concept → There is an inverse relationship between magnitude and frequency
- Low magnitude – high frequency; high magnitude – low frequency

Understanding the Risk of Hazards

- The history of an area can provide insight on its risks of hazards
- The following provide clues:
    - Maps, historic documents, journals, aerial photos
    - Weather and climate data
    - Craters, faults, valleys

The Geologic Cycle

- Throughout Earth's 4.6 billion year history, the materials on or near the surface have been created and modified by physical, chemical, and biological processes
- These processes are called the geologic cycle, which encompasses the following:
    - Tectonic Cycle
    - Rock Cycle
    - Hydrologic Cycle

Tectonic Cycle

- Involves the creation, movement, and destruction of tectonic plates
- Tectonic plates → Large blocks of the Earth's crust that form its outer shell; there are 14 plates
- New land is formed at mid-ocean ridges and land is destroyed at Subduction zones
- The process is driven by Earth's internal energy

Earth's Internal Structure

- The inner core is extremely hot and solid
- The asthenosphere (upper mantle) is composed of hot magma with some flow
- The lithosphere is a thin and brittle crust

Plate Tectonics

- The crust forms the upper part of the lithosphere and is broken into fragments (plates)
- Two types of crust:
    - Oceanic: dense, thin (average 7km thickness)
    - Continental: relatively buoyant, thick (averages 30km thickness)
- Movement of the plates is caused by convection currents that originate in the hot inner core
- Relatively buoyant → Less dense
- Mountains on the continental crust
- Application question: If we have 2 plates coming together, one made of oceanic crust and one of continental crust. Which plate will sink beneath the other plate?
    - Oceanic plate will sink below the continental plate because the more dense material will always want to sink
- Plate boundaries do not tend to match up with continental or oceanic boundaries
- The movement of plates caused dynamic events on Earth's surface, especially at plate boundaries
- Types of plate boundaries → Divergent, convergent, transform

Plate Boundaries

- 200 million years ago → Pangaea
- Mount Everest → Highest mountain on Earth
- California is on a different plate than the rest of the continent

Divergent Plate Boundaries

- At these boundaries, plates move away from each other
- New land is created at these locations
- Divergence results in seafloor spreading and causes oceanic ridges to form (i.e. the Mid-Atlantic Ridge)
- Country that sits in the middle of the mid-Atlantic ridge → Iceland → Built on volcanoes

Convergent Plate Boundaries

- At these boundaries, plates move toward each other
- Collisions involving oceanic and continental crust result in Subduction zones:
    - Dense ocean plates sink and melt
    - The melted magma rises to form volcanoes
- Collisions involving two continental plates result in collision boundaries:
    - Neither plate sinks
    - Tall mountains tend to form (Himalayas)
- What happens if 2 plates have the same density and they collide?
    - Neither plate sinks; land pushes upward; ex. India, Asia

Transform Boundaries

- At these boundaries, plates slide horizontally past each other
- The zone along which this movement occurs is called a transform fault
- Most of these faults are located beneath oceans, but some occur on continents
    - Ex. San Andreas Fault
- Faults in Ontario → reason why we have minor earthquakes

San Andreas Fault

- Everybody to the west of the red line (fault) is going to eventually break off from the rest of the continent
- Fault passes through San Francisco → San Francisco is known for earthquakes

Hot Spots

- Found away from plate boundaries
- Spots where magma rises up from deep in the mantle
- Magma erupting at the surface results in the formation of volcanoes
- Strings of islands are usually indicative of a hot spot → Ex. Hawaiian Islands
- "Big Island" → Hawaii → Only island with active volcanoes
- Position of hot spots does not change, but the plate moves so the position of the island changes
- When lava cools, it forms land → only reason why Hawaii is there is because lava cooled

Rock Cycle

- A rock is an aggregate of one or more minerals
- A group of interrelated processes that produce the 3 different rock types: Igneous, sedimentary, metamorphic
- Igneous rock is formed from ancient volcanoes
- Sedimentary rock is formed by mud that compacts over years
- Metamorphic is a combination of igneous and sedimentary rock

Hydrologic Cycle

- The movement and exchange of water among the land, atmosphere, and oceans by changes in state
- Also referred to as the water cycle
- Solar energy drives the movement of water among the atmosphere, oceans, and continents
- How do we get water to go from the ocean to the atmosphere? → Evaporation

Major Course Themes

- Hazards can be understood through scientific investigation and analysis
- An understanding of hazardous processes is needed to evaluate risk
- Hazards are linked to each other and the environment
- Population growth and socio-economic changes are increasing the risk from natural hazards
- The consequences of hazards can be reduced
- Earthquakes cause tsunamis
- Hurricanes cause flooding
- Consequences of hazards can be reduced through government action and new engineering

Hazard Can Be Understood

- Scientists observe a hazardous event and form a possible explanation for the cause
- From this explanation, a hypothesis is formed
- Data is then collected to test the hypothesis
- Knowing the cause allows for the identification of where hazards may occur
- Knowledge of past events aids in predicting future events

Many Hazards Are Natural Processes

- Events only become hazardous when they disrupt human activity or the environment
- We cannot prevent these processes, we can only respond to them
- The best solution to mitigate loss is preparation

Mitigating Loss

- Accurate predictions and forecasts are necessary
- Prediction: A specific time, date, location, and magnitude of the event
- Forecast: A range of probability for the event
- Some hazards can be predicted. Many can be forecasted
- Earthquakes can be forecasted

Understanding Hazardous Processes To Evaluate Risk

- Risk = (probability of event) x (consequence)
- Consequences: damage to people, property, environment, economics, etc.
- Acceptable risk is the amount of risk that an individual or society is willing to take
- The frequency of an event plays a role in determining acceptable risk

Hazards Are Linked

- Earthquakes may cause tsunami and landslides
- Hurricanes may cause tornadoes and flooding
- Some rock types are more prone to landslides

Increasing The Risk Of Hazards

- The concentration of population creates greater loss of life in disaster
- Human population growth is putting greater demand on Earth's resources
- Rapid population growth is currently occurring in most developing countries
- Many people live in areas that are prone to hazards

Population Growth

- The human population was 6.1 billion in 2000 and 7 billion in October 2011
- India and China combined account for 1/3 of world population
- India is growing faster than China → partly because of the China's regulation on children

Human Footprint

- The risks associated with hazards change as human development expands
- Neighborhoods extend onto hillsides and floodplains
- Urbanization alters drainage and slopes
- Agriculture, forestry, and mining can increase erosion
- In Canada, property damage from hazards is increasing but deaths are decreasing (because of better planning and warning)
    - Property damage is increasing only because Canada has more property

Consequences Can Be Reduced

- The effects of a disaster may be either direct or indirect
- Direct effects: death, injuries, displacement of people, damage to property
- Indirect effects: crop failure, starvation, emotional distress, loss of employment
- We mainly deal with effects in reactive ways. But, a higher level strategy requires a proactive approach
- Reactive approach to hazards:
    - Recovery, search and rescue, providing emergency food, water, shelter, and rebuilding
- Proactive approaches to hazards involves adjustment through:
    - Land-use planning
    - Building codes
    - Insurance
    - Evacuation planning
    - Disaster preparedness
- Artificial control → concrete wall; flood wall; levee, control where water will go

Benefits Of Hazards

- What are these benefits called? → Natural service functions
- Flooding provides nutrients for soil
- Landslides from natural dams to create lakes
- Volcanic eruptions create new land

Climate Change And Natural Hazards

- Global climate change is currently the most important environmental issue facing the Earth
- As climate changes, the frequency of some natural processes will increase
- Sea level rise from melting ice sheets will cause more coastal erosion and flooding
- Warmer oceans will cause more frequent hurricanes

Documenting Disasters

- Maintaining databases on disasters can be difficult. Why?
    - Disasters can co-occur (hurricanes cause floods, earthquakes cause landslides, etc.)
    - Mortality can be difficult to count (famine, epidemics)
    - General lack of census taking (in developing countries)

Identifying Disasters

- Some people may consider certain events to be disasters but other people may not
- Eastern Canada 1998 Ice Storm
- Walkerton tainted water
- Canada/U.S. 14-hour power blackout
- Love Canal toxic waste spill – New York
- Three Mile Island nuclear meltdown – Pennsylvania

Defining Disasters

- A threshold has been developed by the Centre for Research on the Epidemiology of Disasters (CRED):
    - 10 or more deaths per event, or
    - 100 or more persons affected (injured, homeless, etc.), or
    - Government declaration of disaster, or
    - Plea for international assistance
- Exceptions to the CRED threshold:
    - For droughts or famines, at least 2000 persons affected
    - For technological disasters, 5 or more deaths per event

Disasters And Statistics

- Statistical data is often reported in absolute terms (number of casualties, billions of dollars in damage, etc.)
- Statistics must be placed in a community/regional context

Media And Disasters

- The media tends to concentrate on:
    - Human interest
    - Visual impact
    - Events close to home
    - Prioritized according to a North American perspective
- In a study by Adams (1986), the death of one North American = the deaths of
  3 eastern Europeans
  9 Latin Americans
  11 Middle Easterners
  12 Asians

Disasters And impacts

- Earthquakes tend to cause more deaths
- Floods affect more people (homelessness) but have fewer casualties
- Droughts lead to economic losses (agriculture) in developed countries but famine in developing countries
- Drought is a hazard to economics
- The impacts are greatest in less developed countries whether measured in absolute terms (i.e. deaths) or relative terms (i.e. deaths per 100,000)

Disaster Impact Trends

- Most impacts have increased over time:
    - Property damage
    - Persons affected
    - Deaths
- Economic damages are increasing at a faster rate than deaths

Haiti Earthquake

- Haiti has been the poorest country in the western hemisphere for many years
- The M7.0 earthquake occurred on Jan. 12, 2010
- One of the worst natural disasters in history; the death toll was over 220,000
- The epicenter was 25km from Port-au-Prince (the capital city)
- Occurred along a transform plate boundary
- Destruction was enhanced by poor construction materials and a lack of building codes
- Many buildings in the slums on the surrounding hillsides slid downhill
- The 2nd floor of the presidential palace collapsed as did the prison allowing 4000 inmates to escape
- Haiti shares the island of Hispaniola with nearby Dominican Republic

Reasons For Increases In Impacts From Hazards

- Land Pressure
  - Approximately 1 billion people live on degraded land
  - Poverty and lack of land availability leads to unsustainable farming practices
  - Soil erosion, deforestation, clearing mangroves for monoculture
  - Mangroves can protect against storm surges
  - Monoculture results in a loss of biodiversity
  - Mangrove → Swampy area
  - Problem with monoculture → If disease is in one crop, it spreads to the rest
- Urbanization
  - People are increasingly moving from rural areas to urban areas
  - Slums and squatter settlements are quickly growing in less developed countries

Vulnerability To Disasters

- The vulnerability for a particular location is a function of the resiliency and reliability for that location
- Resiliency → The rate of recovery from the occurrence of an event
  - How quick can we recover?
- Reliability → The frequency with which protective devices against disasters fail
  - Protective devices → Flood walls
- Reliability is often lower in less developed countries

Risk

- Risk assessment → The process of estimating the likelihood that a particular hazard will harm human health
- Risk management → It involves deciding whether or how to reduce a particular risk to a certain level and at what cost
- Risk is viewed as subjective
- What we as individuals consider to be risky is based on our own assessment
- Probabilistic risk assessments are not a modern phenomenon
- There are religious examples that aim to assess the risk to the soul based on moral conduct

Probabilistic Risk Assessment

- Pascal (1657)
  - The expected value of accepting Christianity outweighs the expected value of rejecting it

	Accept Christianity	**Reject Christianity**
God Exists	Soul saved	Eternal damnation
God does not exist	Miss out on pagan fun	Pagans not "punished"

  - Choosing the column of accepting Christianity is better

Risk Assessment Data Issues

- Event Data
  - It is best to have at least 100 years of data
  - The amount of data is not available for several hazards (high-magnitude earthquakes, nuclear accidents, etc.)
- Loss Data
  - This is often less available than event data
  - Dollars must constantly be adjusted for inflation

Statistical Analysis

- R = P * L
- R = risk
  P = probability of hazard occurrence
  L = loss (health, economic, etc.)
- Interpreting Probabilities
  - Cumulative probabilities sum to 1 therefore we can read each probability as a percent
  - 0.01 is something with a 1% chance of happening

Risk Analysis Event Trees

- Used when the event database is inadequate (too small)
- The chain of events leading to a disaster must be known
- Probabilities within the chain must be calculatable

Estimating Risk

- What is the risk associated with a technological system?
  - The overall reliability of a technological system is the product of two factors
  - System reliability = Technology reliability * Human reliability
  - With careful design and maintenance, a system such as a nuclear power plant or space shuttle can achieve a high degree of technological reliability
  - Human reliability is usually lower than technology reliability and is difficult to predict
  - Suppose the technology reliability of a nuclear power plant is 95% and human reliability is 75%
  - System reliability is 71%. (0.9*0.75*100 = 0.71)
- The dependence of even the most carefully designed systems on unpredictable human reliability helps explain tragedies such as the Chernobyl nuclear power plant accident and the Challenger and Columbia space shuttle accidents

Risk Analysis

- In terms of the number of premature deaths per year, the greatest risk is poverty
- Poverty is linked to:
  - Malnutrition
  - Increased susceptibility to fatal diseases
  - Lack of access to health care
  - Contaminated water supplies
- The reduction of poverty would do far more to improve longevity and human health than any other measure
- Indirect benefits of reducing poverty:
  - Stimulate economic development
  - Reduce environmental degradation
  - Improve human rights

Risk Perception

- Many people are not concerned with high-risk activities that are done voluntarily
- Motorcycling (1 premature death in 50 participants)
- Smoking (1 in 300)
- Driving a car (1 in 4200)
- Yet, the same people can be terrified by West Nile Virus (1 in 1 million) or plane crashed (1 in 9 million)

Factors Influencing Risk Perception

- Risks from hazards are more accepted if they are perceived to:
  - Be voluntary vs. imposed
  - Be under out control vs. controlled by others
  - Have clear benefits vs. little or no benefit
  - Be natural vs. anthropogenic
  - Be statistical vs. catastrophic
  - Be familiar vs. exotic
  - Affect mainly adults vs. children

Improving Our Risk Perceptions

- How can we become better at estimating risks?
    - Carefully evaluate what the media presents
    - Compare risks (the question is not 'is it safe?' but rather 'how risky is it compared to other risks?')
    - Concentrate on the more serious risks to your health and don't worry about risks over which you have little control

Changing Nature Of Risk

- A shift in the nature of risks:
    - Infectious diseases → Chronic degenerative diseases
    - Accidents shift from the workplace to outside of the workplace (i.e. automobile)
    - Natural hazards have less of an impact (human casualties) in developed countries
- There has been an increase in new hazard threats
    - Most technological hazards with a lower probability of high catastrophic potential
    - Nuclear technology, chemical spills, pesticides, ozone depletion, acid precipitation
- We have an increased ability to measure risks to our health quantitatively
    - North American life expectancy is increasing
- There is an increased role of government in risk assessments and risk management
    - Departments devoted to disaster relief, traffic safety, public health, etc.
- There is an increased involvement of laypeople in risk management decisions
    - Green Peace, Sierra Club
- As countries transition from developing to developed, there are increased public expectations and demands for protection
    - Creates pressure on governments and sometimes expectations can be unrealistic

Tsunami

- Tsunami is Japanese for "harbour wave"
- Produced by the sudden displacement of water
- Events capable of triggering tsunami:
    - Earthquakes that cause uplift of the seafloor
    - Landslides
    - Volcano flank collapse
    - Submarine volcanic eruptions
    - Meteorites
- Not a title wave

Historic Tsunami

Date	Cause	Human Casualties
1755	Lisbon Earthake (M 9.0), Portugal	20,000
1883	Krakatoa Volcanic eruption (VEI 6), Indonesia	36,000
2004	Sumatra Earthquake (M 9.1), Indonesia	230,000
2011	Tohoku Earthquake (M 9.0), Japan	15,000

Earthquake-Triggered Tsunami

- Earthquakes can cause tsunami in 2 ways:
    - Through displacement of the seafloor
    - By triggering a landslide that enters water
- Generally, an earthquake must be of at least M 7.5 in order to trigger a tsunami
- Tsunami develop in a 4 stage process
- Stage 1:
    - Displacement of the seafloor sets waves in motion that transmit energy outward and upward
    - When the waves reach the surface, they spread outward
- Stage 2:
    - In the deep ocean, the waves move rapidly (can reach speeds of over 500 km/h)
    - The spacing of the wave crests is very large (can be more than 100 km)
    - The height (amplitude) of the waves if often small (less than 1 m)

- Stage 3:
    - As the tsunami approaches land, the water depth decreases
    - The result is the water 'piling up' and causes these effects:
        - Decrease in speed
        - Decrease in spacing of the waves
        - Increase in amplitude
- Stage 4:
    - As the tsunami hits land, it can reach heights of dozen of meters
    - The speed at this time can be up to 50 km/h making it impossible to outrun
    - During some tsunami, the water recedes from the shore and exposes the seafloor

Tsunami Event
- Consists of a series of large waves reaching shore than can last for several hours
- Run-up → The maximum horizontal and vertical distances that the largest wave of a tsunami reaches as it travels inland
- The run-up essentially describes the geographic area impacted by a tsunami

Inundation Maps
- Maps showing run-up of previous tsunami area created to help plan for future events
- Historical records, geologic data, and aerial photography aid in making the maps
- Many communities on Vancouver Island have such maps and development restrictions exist in tsunami-prone areas

Types of Tsunami
- Distant tsunami → A tsunami that travels thousands of kilometers across the open ocean
    - On remote shorelines across the ocean, reduced energy lessens the impact
    - Also called tele-tsunami
- Local tsunami → A tsunami that affects shorelines a few kilometers to about 100 km from its source
    - Because of the short distance, local tsunami provide little warning

Regions At Risk
- Coasts located near Subduction zones or across ocean basins from Subduction zones are most at risk
- 85% of tsunami are generated in the Pacific Ocean
- Areas at greatest risk are around the Pacific Ocean, the northeast Indian Ocean, and the Mediterranean Sea

Effects Of Tsunami
- Primary Effects:
    - Flooding and erosion destroy beaches, coastal vegetation, and buildings
    - After the tsunami retreats to the ocean, scattered debris is left behind
    - Most tsunami deaths are from drowning. Injuries result from physical impacts with debris
- Secondary Effects:
    - Generally occur after the event is over
    - Fires may develop due to ruptured gas lines or from ignition of flammable chemicals
    - Water supplies may become polluted and water-borne diseases (cholera) may spread

Natural Service Functions
- Tsunami can carry fertile sediment and oil onto the land that can then be used for agriculture

Indian Ocean Tsunami Of 2004
- Occurred on Dec. 26th
- The source was a M 9.1 earthquake off the west coast of Sumatra (an island in Indonesia)
- 3rd most powerful earthquake in world history
- The earthquake occurred in a Subduction zone between the Burma and Indian-Australian plates
- These plates had been locked for over 150 years allowing strain to build
- The rupture caused some areas along the coastline to subside below sea level
- The tsunami reached nearby Indonesian islands within minutes of the earthquake
- Countries bordering the Indian Ocean did not have a tsunami warning system like the Pacific Ocean
- Over 230,000 people died
- People in the area were ignorant of the early warning signs (such as the receding sea)

Lessons From The Tsunami

- Effective tsunami warning systems are needed in all ocean basins where tsunami can occur
- In 2006, a new warning system became operational in the Indian Ocean
- Once a warning has been issued, emergency officials must have a plan for evacuating residents
- Earthquake and tsunami education is necessary for people who live on or visit coastlines
- Indonesia is the 3rd most populated country in the world

Detecting Tsunami

- The Pacific Ocean warning system uses a network of seismographs to estimate earthquake magnitude
- Tidal gauges and sensors connected to buoys verify that a tsunami was produced
- Some sensors sit on the bottom and measure changes in water pressure passing over them
- These are known as tsunameters

Japan Tsunami Of 2011

- Occurred Mar. 11th
- The source was a M 9.0 earthquake off the east coast of Japan
- A tsunami warning was issued nearly an hour before its arrival
- Over 15,000 people died
- The flatter the land, the more the wave can come inland

Categories Of Adjustment

- Modify Loss Burden
    - Loss sharing
    - Spread the burden well beyond immediate victims
    - Insurance, relief aid
- Modify Design
    - Loss reduction
    - Requires a knowledge base on the hazard
    - Retrofitting buildings
- Modify Human Vulnerability
    - Adjust the population to the events
    - Preparedness programs, land use planning, warning systems

Factors Affecting Adjustment Choices

- Hazards are not typically a priority of governments (compared to unemployment, inflation, health care, crime, poverty, etc.)
- Radical vulnerability adjustments are unrealistic (i.e. moving entire communities)
- A cost-benefit assessment is typically required

Losses: Two Scenarios

- Accepting Loss
    - This is the 'free' choice. It is a no-action response
    - People choose to live how they want regardless of the hazard
    - Floodplain housing can be attractive because it may be inexpensive
- Sharing Loss
    - Government intervention response
    - If governments do not intervene after a disaster, there are often political ramifications

Sharing Loss

- Aid can come from external sources (UNICEF), internal sources (government), inter-community sources, or insurance
- Problems with Sharing Loss
    - A disaster of sudden onset is likely to draw more money than another similarly serious disaster
    - Donor fatigue can set in if there are many disasters
    - Recovery can take a very long time in some countries
    - Aid and enthusiasm eventually wanes

Factors Affecting Individual Adjustment

- Order of likeliness of the following hazards occurring at some point in London over the next 50 years
    - Blizzard
    - Ice storm
    - Flood
    - Hurricane
    - Tornado
- Experience → More experience with a hazard results in more likelihood of adjustment
- Material wealth → More resources results in more information and more options
- Personality → Some people are more likely to take risks

Prospect Theory

- Generally, people are more willing to protect against loss than they are willing to gamble on an equivalent gain
- Protecting our assets, protecting against loss

Responses To Hazards

- Cultural adaptation → This type of adaptation may result from changes in an environment
    - Ex. Mackenzie River Delta
        - The discovery of oil forces adaptation as the resource is developed
        - The only people who lived in this area were Inuits; Inuits were forced to adapt to new culture
- Purposeful adjustment → This is an adjustment that is specifically designed to reduce loss or damage
    - Ex. Designing buildings to withstand earthquakes in high-risk areas
- Incidental adjustment → These are not primarily hazard-related but have the effect of reducing potential loss
    - Advances in technology have improved warning systems
    - Increased capacity to store and move grain over long distances has reduced vulnerability to drought
- Absorptive capacity → This is a measure of the ability of individuals or groups to sustain impacts from a hazard
    - Results from combinations of cultural adaptation, purposeful adjustment, and incidental adjustment
    - In parts of Kenya maize, beans, peas, sorghum, and ground nuts are planted all together. This encourages deep roots and is more drought resistant

Cognitive Influences On Choice

- Based on 100 years of data, the estimated probability of a 100-year tornado touching down in Disastertown in 2012 was 0.01
- In 2012 a tornado touched down in Disastertown
- The likelihood of a 100-year tornado touching down in 2013 is considerably less than 0.01 because one struck in 2012. True or False?
    - False
- Gambler's Fallacy → The belief that the occurrence of a chance event influences the probability of future occurrences

Theory of Choice

- Expected Utility
    - Optimize the values
    - Choose on the basis of all expected outcomes
    - Probabilities are multiplied against assessments of value (utility)
    - Potential issue: ascribing probabilities to events usually involves uncertainty

Patterns Of Choice

- There are 4 patterns regarding how people choose to respond to a risk

1. Absorb
    - View the risk as unproblematic or deny it outright
    - The probability is deemed too lwo to worry about
    - Fate is determined by the capacity to absorb losses
    - Ex. San Andreas fault
2. Accept
    - There is awareness of the hazard (no denial)
    - Passive attitude (there is little that can be done to affect the impacts)
    - Hazards are often viewed as acts of God
    - Ex. Nigeria drought

3. Reduce
    - There is awareness of the hazard (no denial)
    - Action is taken to reduce impacts
    - Typically there is emergency action and some preparation
    - Usually people stay in place
    - Ex. Flooding events, snow and wind related hazards
4. Change
    - There is awareness of the hazard (no denial)
    - Radical action may be taken (move away or change the land use)
    - Ex. Australia drought

Social Amplification Of Risk

- No comprehensive theory exists to explain why apparently minor risk events sometimes produce massive public reactions
- Name an event that typically evokes massive public reactions
    - West Nile Virus
    - Y2K
    - Blackout
    - Nuclear meltdowns
- What are some potentially negative impacts of such reactions?
    - Puts pressure on the government to not move toward nuclear power even though it is a clear source of power compared to coal

Evocative Hazards

- Urban Pesticides

Banal Hazards

- Known to be serious but typically evoke little public reaction
- According to a Consumers Union study, eating peanut butter (which contains an average level of 2 parts per billion of aflatoxin) once every 10 days would present a cancer risk of 7 in one million
    - Higher than the estimated risk of cancer from most pesticides

Amplification And Attenuation Of Risk

- Amplification
    - Involves hazards that have a low probability as assessed by experts
    - Elicit strong public concern
- Attenuation
    - Involves hazards that may have serious physical impacts and relatively high probability
    - Elicit weak public concern
- Transmitter → Generates and sends the risk message
- Signal → The message itself
- Receiver
    - The target audience for message signals
    - The original signal may be considerably modified by the time it is received

Signal Value

- Signals can be prescribed values by the receiver
- This is related to the characteristics of the event and the hazard it reflects
- High signal values might suggest that a new risk has appeared or that the risk is different than previously understood

Examples Of Signal Value

- An accident that takes many lives may produce little social disturbance if it occurs as part of a familiar and understood system (such as a train wreck)
- A small accident in an unfamiliar or poorly understood system (nuclear power plant, laboratory) may cause public concern since people may perceive the risk is uncontrollable

Stigmatization

- Process by which negative images are ascribed to places, technologies, and people
- The location of a future event in the area could alter the risk perception because of past events
- Ex. Love Canal, Nevada Test Site
- Nevada Test Site → Where nuclear weapons are tested

Impacts

- Spread of Impact
    - Impacts can spread like ripples and often extend beyond the local area
    - Entire countries, technologies (medication), industries (meat) can be affected
- Secondary Impacts
    - Property values, retail sales, and insurance rates can change in response

Secondary Impacts

- Stigma and property values are typically intertwined
- Ex. There were significant differences between house prices in wildfire affected areas and non-affected areas of Phoenix after a wildfire that the government deemed was very low risk

Risk Perception Theories

- Why do some people feel that technological activities (i.e. nuclear power plants or chemical pesticides) are a major concern while others feel that they are not a concern?
- 5 theories that attempt to explain this:
    - Knowledge
    - Personality
    - Economic
    - Political
    - Cultural

Knowledge Theory

- How was this theory tested?
    - Education level
    - Self reported knowledge
    - Subjects were asked to provide an estimate of annual fatalities from 8 technological activities (aviation, nuclear power, lawn mowers, etc.). Their answers were then compared to actual data
- Hypothesis → Greater knowledge leads to a greater perceived threat

Personality Theory

- This theory was tested using validated measures and questionnaires developed by psychologists
- Hypothesis → There is consistency between the personality type and the perceived threat from hazards

Economic Theory

- This theory is based on the annual income of the subjects
- Hypotheses:
    - The wealth are more willing to take risks with technology because they may benefit more or have more access
    - The poor are less willing because they may deal with any associated burdens (pollution)

Political Theory

- This theory is tested by determining the political ideology of the subjects (20 question survey)
- Hypothesis → Personal views toward risk are related to the political party and policies that they support

Cultural Theory

- This theory is based on the way of life of the subjects (urban, rural, retired, child-rearing, etc.)
- Supported by personal worldviews (i.e. the way the person believes the world does or should operate)
- Examples of worldviews → Hierarchical, egalitarian, individualist
- Hypothesis → The worldview will be correlated to how the person perceives risk

Hierarchical Worldview

- Defines boundaries between superiors and subordinates
- Strong patriotism
- Support for country, right or wrong
- Strong respect for authority (law, order, and obedience are strongly valued)
- Strict ethical standards
- Concern about lack of discipline in youth

Egalitarian Worldview

- Centres on political solutions to inequality
- Belief that world conflict can be eliminated with a more equal distribution of resources
- Support for government efforts to reduce poverty
- Support for high tax burdens on the wealthy
- A lack of trust in large corporations

Individualism Worldview

- Emphasizes personal freedom and choice
- Constraints on individuals should be minimized (lack of support for heavy government regulation)
- Belief that the welfare state destroys individual initiative
- Continued economic growth and private profit are keys to quality of life

Results

- Tests of the 5 theories were performed in a study by Wildavsky and Dake (1990)
- 134 people participated in the study
- Knowledge Theory
    - The results suggested that greater knowledge resulted in greater perceived benefit of technological activities but they were not statistically significant
- Personality Theory
    - Those who perceived technological activities as high risk were less aggressive and more obedient
    - There is no accepted explanation to explain this but there are consistencies with the cultural theory
    - Those with a less aggressive personality were more likely to have hierarchical worldviews
- Economic Theory
    - The results were inconsistent since there was little correlation between income and personal views toward the risks of technological activities
- Political Theory
    - Those who identified as liberals were more likely to see the technological activities as threatening
- Cultural Theory
    - Correlations were evident and all were statistically significant

	"Grave problem"	**"Risk worth taking"**	**Perceived benefit**
Egalitarianism	0.51	- 0.42	
Hierarchism		0.43	0.37
Individualism		0.32	0.34

Summary Of Results

- Knowledge → Inconsistent
- Personality → Consistent
- Economic → Inconsistent
- Political → Consistent
- Cultural → Consistent
- The cultural theory was found to be the best explanation for how people perceived risk

Social Conflict

- The clash of worldviews can sometimes result in conflict whether or not they are based on actual fact
- A wealth of scientific evidence shows warming average temperatures worldwide
    - Environmentalists lobby governments to regulate emissions
    - Economic growth advocates cast doubt on the quality of the data

Mass Wasting

- Downslope movement of rock or sediment as a result of gravity
- The terms mass wasting and landslide are used interchangeably regardless of speed of the fall
- Movement is classified as rapid if it can be detected by eye; if not it is classified as slow or moderate

Classification Of Landslides

- Based on 4 variables:
    - Mechanism of movement
    - Type of material
    - Amount of water present
    - Rate of movement

Mechanisms Of Movement

- 3 basic mechanisms
    - Fall → Rock or sediment dropping off the face of a cliff
    - Slide → Downslope movement along a discrete failure plane
    - Flow → Movement of particles semi-independently of one another, commonly with the aid of water

Rock Fall

- Caused by a fall mechanism
- Involves rock rolling down the slope or falling through the air
- Steep vertical gradient

Slump

- Caused by a slide mechanism
- In a slump, the failure plane is curved upward

Creep

- Caused by a flow mechanism
- Rate of movement ranges from a few millimetres to a metre annually

Forces On Slopes

- The stability of a slope is based on the balance between 2 types of forces:
    - Driving Forces → These move material downslope; they are based on the weight of the material from vegetation, water, etc.
    - Resisting Forces → These oppose downslope movement; they are based on the shear strength of the material

Factor Of Safety

- The ratio of resisting forces of driving forces
- When the ratio is over 1, the slope is stable. When the ratio is under 1, the slope is unstable
- If the factor of safety equals 1, driving forces equal the resisting forces
- The forces are determined by relationships among: material type, slope and topography, climate, vegetation, and, water

Role Of Slope And Topography

- The steeper the slope, the greater the driving forces
- Steepest slopes are associated with rock falls
- Moderate slopes are associated with flows
- Gentle slopes are associated with creep
- Topographic Relief → The height of a hill or mountain above the land below
- Dangerous landslides are more likely in areas of high relief
- High relief means there is a big difference between the top and bottom of the hill

Role Of Climate

- The climate of an area influences the amount of water than infiltrates and erodes the soil
- In dry climates, vegetation is sparse, soil is thin and bare rock is exposed in many areas
    - Rock falls are more likely in these areas
- In humid climates, soil is thick and rock is generally covered with soil and vegetation
    - Flows and creep are more likely in these area

Role Of Vegetation

- Dense amounts of vegetation can slow surface erosion
- How? → Roots add strength and cohesion to the slope
- Improper deforestation often affects the frequency of the landslide hazard

Role Of Water

- Water saturates soil increasing the likelihood of flows
- Following prolonged periods of deep water infiltration, slumps can develop
- Water can erode the base of a slope therefore decreasing the resisting force

Regions At Risk

- Any location with significant variation in topography is at risk
- Factors that increase risk include urban development, deforestation, and climate change

The Frank Slide

- Canada's best-known landslide
- Occurred in 1903 on Turtle Mountain near Frank, Alberta
- Killed 76 people, dammed the Crowsnest River creating a lake, and buried 5 km of railway
- Glaciation, coal mining, and heavy snow were likely contributors to the landslide

Effects Of Landslides

- Approximately 30 people are killed by landslides annually in North America
- Landslides can often block railways and highways in isolated areas thus severely impacting travel
- As urban areas continue to grow, property damage will increase
- There are only 4 highways that connect B.C. to Alberta

Natural Service Functions

- Landslides can create new habitats in forests and aquatic ecosystems
    - Results in an increase of biodiversity
- Landslides can produce sediments containing valuable materials that become concentrated at the base of a slope following an event
- Landslides bring material down from the slopes to where we can easily access the materials; minerals are brought down to us with the materials
- Landslides can tell us that there are valuable minerals up in an area

Human Interaction With Landslides

- Grading of land surfaces for new home and building construction can increase probability of slope failure
- Harvesting timber and urbanization are currently the leading human causes for the increase in landslides
- Timber Harvesting
    - Clear-cutting and the construction of logging roads can cause landslides in geologically unstable areas
    - A lack of surface vegetation and a lack of tree roots enhances soil erosion
- Urbanization
    - Modern engineering has allowed humans to turn hilly slopes into flat land for construction
    - Slopes are destabilized when rock is removed, laws are watered, septic systems are installed, and buildings are constructed
    - All of these add weight to the slope increasing the driving force

Minimizing The Landslide Hazard

- An important first step is recognizing where they are most likely to occur
- Features indicative of unstable slopes include:
    - Cracks on a hillside
    - Recessed crest of a valley wall
    - Large boulders at a cliff base
    - Tilted tree
    - Exposed bedrock with layering parallel to slopes
    - Irregular land surface at a slope base
- Aerial photos are used to detect some of these features and then hazard maps can be produced

Prevention Of Landslides

- Drainage Control
    - Keep water from running across the slope or from infiltrating into the soil
    - Pipes and drains aid in removing groundwater
- Leveling the Slope
    - Material from the upper slope can be moved to the slope base if the slope is noticed to be top-heavy
- Slope Supports
    - Examples of these include retaining walls, rock bolts, and metal screens

Landslide Warning Systems

- Electronics and tiltmeters are currently used to detect vibrations along a slope
- Some rock fences along railways in western North America are linked to signal systems
- Wells and rain gauges on slopes can identify when a precipitation threshold has been reached
- Tiltmeter → Instrument that measures very small ranges from the horizontal level

Perception Of Landslide Hazards

- The relative infrequency of large landslides tend to reduce awareness of the hazard
- People continue to build in areas prone to the hazard
    - Requires adjustments in order to minimize deaths and property damage

Adjustments To The Landslide Hazard

- It is crucial to safely cite critical facilities (hospitals, schools, power plants, etc.) away from landslide-prone areas
- Reducing water pressure through good drainage is the best corrective measure to counter the hazard since this will decrease the driving force
- Analyzing landslide hazard maps and avoiding the purchase of a home in a hazardous area is the best way to reduce risk

The Atmosphere

- Composed of nitrogen (78%) and oxygen (21%)
- The remaining 1% consists of water vapour, carbon dioxide, and other 'trace' gases
- Water vapour in the atmosphere can result in cloud development and the formation of precipitation
- Water vapour comes from evaporation from the oceans

Structure Of The Atmosphere

- All weather (i.e. clouds and precipitation) is confined to the troposphere
- The ozone layer protects us from the Sun's harmful UV rays; it is found in the stratosphere
- Troposphere → 11 – 12 km above the ground

Clouds

- Cloud names generally contain a prefix and a suffix
- The prefix describes the height of the cloud; the suffix describes its appearance
- Prefixes:
    - High cloud: cirro-
    - Mid-level cloud: alto-
    - Low cloud: strato-
- Suffixes:
    - Puffy: -cumulus
    - Flat: -stratus
- Ex. A high puffy cloud is called a cirrocumulus cloud
- Clouds that produce precipitation contain "nimb" in their name
- Nimbostratus → prolonged precipitation (springtime)
- Cumulonimbus → heavy precipitation

Thunderstorms

- At any moment, there are approximately 2000 thunderstorms occurring on Earth
- Thunderstorm development requires:
    - An unstable environment (a steep vertical temperature gradient)
    - Water vapour
    - Rising air (or a lifting mechanism, i.e. a cold front)
- Further south you go, the more storms you see
- London & Windsor are storm capitals in Canada

Thunderstorm Development

- Thunderstorms develop in 3 stages → Cumulus, mature, dissipative
- Most storms pass through all 3 stages in 1 hour

Hail

- Formed during thunderstorms in very tall clouds
- Updrafts in the cloud repeatedly force a water droplet upward
- The droplet develops a ring of ice around it each time it enters the cold part (the top) of the cloud
- The ball of ice eventually becomes heavy enough to fall to the surface
- China (1995) → Hail the size of basketballs killed 37 people
- Measure hail using everyday objects → baseball, softball, etc.

Lightning

- A spark of electricity occurring in a cloud
- The majority of lightning strikes within cloud
- Lightning heats the air causing the air to expand and creating a shockwave (thunder)
- Sometimes the atmosphere refracts thunder making it inaudible
- Only 30% of lightning is from cloud to ground
- There is always thunder after lightening
- Lightening will always seek the fastest way into the ground
- Car is a safe place to be because the metal will carry the current around you, into the tires, then into the ground

Causes Of Lightning

- What is the main requirement for lightning? → Spark
- The interaction of ice crystals, hailstones, and water droplets result in a separate distribution of charges in the cloud

Tornado

- A rotating column of air blowing around intense low pressure where the column is touching the ground
- A rotating column not touching the round is called a funnel cloud
- Biggest severe hazard around London
- Low pressure → Disturbed weather
- Can't be called a tornado until it actually touches a surface → Until then it is just called a funnel cloud

Characteristics Of Tornadoes

- Approximately 300 metres wide
- Travel from the southwest toward the northeast at an average speed of 50 km/h
- Tend to exist for less than 30 minutes with a defined life cycle
- Spring is the most common season for tornadoes

Tornado Life Cycle

- Tornadoes exist in 3 defined stages:
    - Organizational Stage
        - Wind shear causes rotation to develop
        - A funnel cloud protrudes from above
        - Dust and debris rotates beneath
    - Mature Stage
        - Most severe damage occurs at this stage
    - Rope Stage
        - The tornado stretches out and weakens
- Wind shear → A change in wind speed or direction over a horizontal or vertical distance

Classifying Tornadoes

- Enhanced Fujita Scale → Tornadoes are classified on a scale of EF0 to EF5, based on their wind speed
- EF5 tornadoes → Wind speed over 415 km/h
- Less than 1% of tornadoes are classified as EF5
- Most EF5s happen in the U.S. tornado valley

Notable Tornadoes

- April 3, 1974 "Super Outbreak"
    - 148 tornadoes touched down in a line from Alabama to Ontario
- May 22, 2011
    - An EF5 killed 162 in Joplin, Missouri

Tornado Alleys

- The U.S. experiences the most tornadoes on Earth. Canada experiences the 2nd most
- United States Tornado Alley → Kansas, Oklahoma, Texas
- Canada Tornado Alley → Southwestern Ontario
- Why do these tornado alleys exist?
    - They are areas where air masses commonly collide
    - They are areas of relatively flat land (this allows for undisturbed rotation)
- Mountains stop tornadoes from forming

Canada's Tornado Alley

- Tornadoes in Ontario occur when a southwesterly wind brings warm, moist air from the Gulf of Mexico
- The warm, moist air often interacts with cooler lake breezes

Goderich Tornado

- The tornado killed 1 person and destroyed much of the historic town core on Aug. 21, 2011
- It was the first EF3 tornado to touch down in Ontario in 15 years
- Spotted over Lake Huron on RADAR and a warning was issued 12 minutes before it reached the town
- Lake Huron is warmest in late August

Joplin Tornado

- Multi-vortex tornado 1.5 km in width
- The most costly in the U.S ($2.2 B) and the deadliest in the U.S. since 1947

U.S. Tornado Outbreak Of 2011

- The largest tornado outbreak in world history occurred from April 25th to April 28th
- 336 tornadoes touched down in southeast U.S. and 346 people were killed (239 in Alabama)
- More people were killed by tornadoes in 2011 than any other year since 1927
- When tornadoes touch down, they almost always move in a perfectly straight line
- Why do they move in a straight line? → Laws of physics; no reason to move unless something shifts it

Cyclonic Weather Systems

- Tropical Cyclones
    - Form over warm waters at latitudes of 5 – 20°
    - Include tropical depressions, tropical storms, and hurricanes
    - Contain high winds, heavy rain, and storm surges
- Mid-latitude Cyclones
    - Form over land or water in temperate regions at latitudes 30 – 70°
    - Associated with fronts
    - Contain rain, snow, freezing rain, etc.

Tropical Cyclone Development

- Tropical Disturbance → A large area of low pressure with unsettled weather
- Tropical Depression → An unorganized area of thunderstorms
- Tropical Storm → An organized area of storm with wind of 65 – 120 km/h
- Hurricane → An intense area of low pressure with wind over 120 km/h

Tropical Cyclones

- Referred to by different names in different parts of the world
- Require a water temperature of at least 26°C
- Do not tend to form on either side of South America because of the temperature of the water
- There has only been 1 hurricane in history east of South America

Components Of Hurricanes

- Eye → A region in the centre with light winds and clear to partly cloudy skies
- Eyewall → A ring of intense storms that whirl directly around the eye
- Spiral Rain Bands → Rings of tall clouds and heavy rain that exist throughout the hurricane
- The further away you go from the eye, the less severe the rain is

Anatomy Of A Hurricane

- Separate rows of clouds because around each row, the air is sinking
- Clouds form when air rises
- Air is sinking in the eye
- Where air sinks, the cloud cannot form

Naming Hurricanes

- Names were first assigned to hurricanes in 1953
- Alternating male and female names are used in alphabetical order (5 letters are skipped)
    - Q, U, X, Y, Z are skipped
- The name is retired if the hurricane produced notable damage. Ex. Andrew, Katrina
- Names were exhausted for the first time ever in 2005 when 27 hurricanes occurred
    - The final hurricanes that year were named after Greek letters
- List of 21 names

Hurricane Movement

- Hurricanes typically travel very slowly (less than 20 km/h)
- Because wind in a hurricane rotates counter-clockwise, wind speed varies over the area of the hurricane
- If a hurricane is moving to the northwest, where will its highest winds be located?
    - Northeast Quadrant
    - Weakest winds would be in the opposite direction → Southwest Quadrant

Storm Surge

- Most devastating effect of hurricanes
- Results from powerful winds creating an abnormal rise in sea level
- Hurricane Andrew (1992) → 23 ft storm surges were reported in Florida

Classifying Hurricanes

- Hurricanes are classified by the Saffir-Simpson Scale
- Classification is similar to tornadoes (both are based on wind speed)
- Hurricanes don't have a category 0 → Starts at 1

Regions At Risk

- In North America, areas at highest risk are found along the coasts of the Atlantic Ocean and the Gulf of Mexico
- The official hurricane season ranges from June 1st to November 30th
- Most hurricanes occur in August and September because this is when the water is warmest
- Late August is when the water is warmest
- Air is warmest in July

Hurricanes In Canada

- Hurricane Juan: Sept. 29, 2003
    - Category 2 hurricane when it made landfall near Halifax
- Hurricane Hazel: Oct. 15, 1954
    - 81 people were killed when intense flash floods in Toronto swept away homes; no other disaster has caused that many deaths in Canada to this day
    - Flooding of the Humber River caused the most damage

Fog

- A cloud with its base at the Earth's surface; it reduces visibility to less than 1 km
- Occurs at night when the air cools to the dewpoint (at which water vapour will condense into droplets)
- Can also form when warm air moves over a cold body of water

Snowstorm As Hazards

- The worst natural disaster in Detroit (in terms of death toll) was a snowstorm in 2003
    - 36 people died from heart attacks while shoveling snow from the storm

Blizzards

- Intense winter storm with very specific conditions:
    - Wind at least 40 km/h
    - Snow falling or blowing snow occurring
    - Visibility less than 1 km
    - All of these must occur for at least 3 hours
- More common in western Canada

Lake Effect Snow

- Snowbelts are found downwind of the lakes (in winter, the wind is often from the northwest)
- Lake-effect snow is caused by cold air moving over relatively warm water
- London is located in the Lake Huron snowbelt; this results in a relatively high annual snowfall
- All of southern Ontario frequently experiences lake effect clouds in winter
- Lake effect snow ceases when the lakes freeze over (this commonly occurs in February)

Sandstorms

- Occur in arid and semi-arid regions
- Especially common in the Middle East where they are called haboobs
- What causes a haboob to form? → Downdrafts on the leading edge of a thunderstorm

Ice Storms

- Mainly caused by freezing rain
- Freezing rain is rain that freezes upon impacting the surface

Droughts

- Extended period of unusually low precipitation
- Affect more people in North America than any other hazard
- Produce water shortages that can lead to crop failure. In developing countries, this may lead to malnutrition and famine
- Linked to global weather patterns and are a normal part of the climate system

Temperature And Humans

- Wind Chill → A correction factor to a temperature reading caused by the presence of wind making the air feel cooler than the temperature suggests
- Humidex → A correction factor to a temperature reading caused by high levels of humidity making the air feel warmer than the temperature suggests

Minimizing Severe Weather Hazards

- Forecasting has improved dramatically with better technology; 3-day forecasts are very accurate today
- Weather satellites detect cloud cover and aid in forecasting hurricanes and mid-latitude cyclones
- RADAR detects precipitation (both the type of precipitation and intensity)
- 3-day forecasts → 96% accurate
- 5-day forecasts → 60% accurate

Hazardous Weather

- The most important job of a forecaster is to alert the public of potentially dangerous weather
- Alerts are broken into 3 categories:
    - Watch → An alert covering a wide area. Conditions favour the development of hazardous weather but none has been reported
        - Ex. Tornado watch, winter storm watch
        - Watch is less severe because it just means that something can happen
    - Warning → An alert that usually covers smaller areas. It indicates that hazardous weather is currently occurring in the area
        - Ex. Severe thunderstorm warning
    - Advisory → Used to alert the public of less hazardous weather conditions
        - Ex. Dense fog advisory

The Climate System

- Climate is a function of the interaction of many 'spheres':
    - Atmosphere: gases
    - Hydrosphere: oceans, large bodies of water
    - Lithosphere: plate tectonics, Orogeny
    - Cryosphere: glaciers, ice sheets, snow cover
    - Biosphere: vegetation, animals, humans

Climate Change

- Over the last billion years, there have been several worldwide ice ages
- Between ice ages, the global climate was at times slightly warmer than it is today

The Last Glacial Period

- All of Canada was covered with ice 180,000 years ago (except for northern Yukon)
- Lower sea levels at that time exposed the Bering land bridge

Climate In Recent History

- There has been a rapid rise in temperature over the past 100 years
- This corresponds to human industry and the increase of greenhouse gases
- Carbon dioxide absorbs radiation
- Radiation relates to temperature

Mean Temperatures Since 1955

- In 50 years → 2 to 3 degrees Celsius warming

Causes Of Climate Change

- 4 general causes:
    - Variations in solar radiation
    - Changes in composition of the atmosphere
    - Changes in the Earth's surface
    - Variations in Earth's orbit

Variations In Solar Radiation

- The sun tends to emit more energy during periods of high sunspot activity
- Sunspot → A cool region of high magnetism on the sun
- Sunspots occur in cycles and reach a maximum every 11 years
- Sunspots are cool areas on the Sun that are surrounded by faculae (bright areas that emit high amounts of energy)
- Solar output regularly changes on the order of 0.1 – 0.2 in relation to sunspot cycles
- With more sunspots, there is increased solar output
- Maunder Minimum (1645 – 1715) → A time period with no sunspots; this corresponds to a time period known as the Little Ice Age

Changes In Composition Of The Atmosphere

- Aerosols → Tiny particles in the atmosphere that reflect shortwave radiation
    - Ex. Dust, sand, ash, some pollutants
- Mt. Tambora (1815), Indonesia → Volcanic ash reached the stratosphere and surrounded the entire world
- 1816 was known as "the year without a summer"
- The addition of greenhouse gases (carbon dioxide, water vapour, methane) increases global temperature
- CO2 has a long residence time in the atmosphere (100 years)
- If we reduce CO2 today, the effects will not be felt for decades
- Every 100,000 years, there's a spike in the Earth's temperature

Determining Past Climates

- Ice cores
    - The width of an ice layer provides insight on the temperature and snowfall of that year
    - Each year, a new layer of ice forms
    - Bubbles of air are trapped in the ice
    - Ice cores provide climate data for up to 600,000 years in the past
- Dendrochronology
    - The study of tree rings
    - Wider tree rings correspond to warmer or wetter years
    - Tree rings provide climate data for up to 1000 years in the past

Changes In The Earth's Surface

- Theory of Plate Tectonics → The continents have moved over time
- Ice tends to form on land
- Continents located on colliding plates results in uplift and the creation of mountains
- Implications → This affects wind, temperatures, and precipitation patterns of the surrounding landscape
- Mountains affect precipiation patterns
    - West side → Wet
    - East side → Dry

Variations In Earth's Orbit

- Milankovitch Theory
    - Proposes that 3 separate phenomena relating to Earth's orbit lead to climate change
    - 3 Milankovitch Cycles:
        - Eccentricity
        - Precession
        - Obliquity

Milankovitch Cycles

- Eccentricity → Changes in the shape of Earth's orbit from circular to elliptical (100,000 year cycle)
- Precession → The wobble of the Earth's axis (23,000 year cycle)
- Obliquity → Changes in the tilt of Earth's axis (41,000 year cycle)

The Greenhouse Effect

- Why does it exist? → Greenhouse gases allow solar radiation to pass through but they absorb infrared radiation
- Main greenhouse gases:
    - Carbon dioxide
    - Water vapour
    - Methane
- If we do not have a greenhouse effect on earth, the average temperature on earth would be so cold that it would not be able to support life (-18)

Enhancing The Greenhouse Effect

- The greenhouse effect is not a concern, however the enhancement of the greenhouse effect by humans is a concern
- Why?
    - Adding greenhouse gases results in climate change
    - Increasing CO_2 enhances the greenhouse effect
- Why?
    - Because more infrared radiation from the earth is absorbed by the atmosphere

Ozone (O_3)

- Gas composed of oxygen with an odour similar to chlorine
- Forms naturally in the stratosphere
- Forms in the troposphere by chemical reactions with other gases
- Ozone is good as long as it is no where near us
- We want/need the natural ozone layer to protect us from the harmful rays of the sun

Ozone In The Stratosphere

- Ozone in the stratosphere is important because 7% of some of the Sun's radiation is ultraviolet; this radiation is harmful to humans
- The ozone layer protects us from the harmful UV rays of the sun (UV < 0.2μm)

Destruction Of The Ozone Layer

- Chlorofluorocarbons (CFCs) are the major reason for the depletion of the ozone layer during the 1900s
- CFCs were found in spray cans, hair sprays, and inefficient appliances
- Non-essential uses of CFCs were banned in North America in the 1970s
- Montreal Protocol (1987) → A worldwide agreement among countries to reduce CFC concentrations
- Ultraviolet radiation breaks up CFC molecules causes the release of chlorine
- Chlorine rapidly destroys ozone
- A CFC molecule can remain in the atmosphere for many decades
- Though CFCs have declined since 1970, there is little decline recognized in the atmosphere
    - Why?
        - Because of the high residence time of CFCs
- Decreased amounts of stratospheric ozone have resulted in increased cases of skin cancer
- Skin cancer rates have doubled since 1950

Acid Precipitation

- Precipitation that combines with pollutants that turn the precipitation acidic
- Main sources → Sulfur oxides, nitrogen oxides
- Effects of Acid Precipitation:
    - Slow tree growth, reduce fish population in lakes, erodes materials
- Currently, 14,000 lakes in Canada are acidified
- The pH scale is a measure of acidity
- Scale Range → From 0 to 14; 7 is neutral and below 7 is acidic
- Precipitation is naturally acidic (~5.5)
- Most common in eastern North America
- Nitrogen oxides and sulfur oxides combine with water vapour to form nitric and sulfuric acid
- Aquatic life can't survive when pH < 4.8
- 1991 → Canada-U.S. A Quality Agreement

Feedback Mechanisms

- Positive feedback often enhances climate change
- Less snow/ice on the ground decreases reflectivity of solar radiation (because snow is highly reflective)
- After snow/ice melts, more solar radiation is being absorbed rather than reflected
    - Leads to warmer conditions. It is the reason why the polar regions are warming the fastest

Climate Models

- Estimates by how much the Earth will warm
- Climate models predict that over the next 100 years, the Earth will warm by at least 1.5°C
- How do the models work? → By solving a series of mathematical equations
- What do he variables in the equation represent? → Greenhouse gases, solar radiation, other climatological components

Human-Induced Climate Change

- "Human activities are increasingly altering the Earth's climate. These effects add to natural influences that have been present over Earth's history"
- "Scientific evidence strongly indicates that natural influences cannot explain the rapid increase in global near-surface temperatures observed during the second half of the 20th century"

Slowing Climate Change

- Kyoto Protocol (1997) → A global agreement aiming to slow climate change
    - Objective → To reduce greenhouse gas emissions to 5% below 1990 levels by 2010
    - "Think Globally, Act Locally"
    - China was not required to meet this objective
    - Australia did not sign because they are an island country and their power comes from power plants and they were worried they wouldn't be able to get power in without using coal

Impacts Of Climate Change

- Polar areas would warm the most
- Boreal forests will expand northward, agriculture will shift northward
- Precipitation patterns would change thus affecting habitats
- There will be increased frequency and intensity of storms and hurricanes

Sea Level Rise

- As sea level rises, erosion is affecting areas further inland; some areas are eroding at 10 m annually
- Sea level is projected to rise as global climate changes and ice sheets continue to melt
- North American cities at greatest risk include Vancouver, Miami, New Orleans, and New York
- Maldives is an island nation of 300,000 people in the Indian Ocean
    - About 80% of the country is less than 1 m above sea level
    - Seawalls have been built around many of its islands to protect from waves up to 2 m in height

Climate Change And Human Health

- Climate change affects ecological systems, food production and economic activities
- Impacts of climate change:
    - Spread of infectious disease (malaria)
    - Increase in extreme weather events

Impacts On Human Health In Canada

- Climate change is predicted to cause:
    - An increase in heat wave related deaths
    - An increase in allergic disorders
    - Enormous impacts in northern Canada on Native populations and wildlife

Impacts of Climate Change On Biodiversity

- Coral is very sensitive to changes in water temperature

Deaths From Climate Change

- Climate change since the mid-1970s is contributing to the cause of over 160,000 deaths per year
- These deaths are attributed to an increase in malaria and malnutrition in less developed countries

Adaptation Measures

- To adapt to the effects of environmental change, governments should use resources to:
    - Monitor for emerging infectious diseases
    - Improve emergency management plans and early warning systems
    - Upgrade water and wastewater treatment facilities

Cost-Benefit Analysis

- This is how we decide between action and inaction
- In terms of climate change, governments are in a difficult position:
    - They must balance the economic costs of mitigation against the uncertainties of scientific predictions

Human-Environment Relations

- What is the relationship between humans and nature?
- 2 philosophies:
    - Humans are simply one component of the natural world
    - Humans are separate from nature
- Out relationship with nature dictates our actions
- 2 philosophies:
    - Living in harmony with nature (sustainable development)
    - Exploiting nature for economic gain (ignore the true costs of resource extraction)

Natural Resources

- Many natural resources are finite
- Using resources creates waste products
- Problem
    - We have created a society and economy in which these 2 realities were neglected
    - There is resistance to changing the way resources are extracted

The Precautionary Principle

- Examples of its use:
    - Insurance policies
    - Preventative maintenance
- Applied to environmental change → Balance between the potential harm and costs of inaction compared to the potential wasted costs of acting unnecessarily
- Precautionary Principle
    - When there is a risk involved to humans or the environment, we should still act even if there is some uncertainty about the risk
    - We have a social responsibility to protect the public and the environment from harm

Economics Applied To Climate Change

- Fast action will not occur until either a crisis is at hand or until a solid economic argument can be made in terms of financial costs and savings
- Costs of anthropogenic environmental change:
    - Damage due to change
    - Mitigating action to reduce the amount of change
- Since climate change is inevitable, the first cost is already unavoidable

Cost Of Damage vs. Cost Of Mitigation

- The cost of damage estimated by economists is as high as $125 US per ton of carbon
- Mitigation costs will be high if implemented rapidly (imposing strict emission limits)
- However gradual emission reductions should greatly reduce the mitigation costs:
    - Improving efficiency of energy use
    - Converting to non-fossil fuel energy

Natural Capital

- Accounting for “natural” capital is seldom done
- We have dealt with this difficulty by creating regulations and setting aside natural resources for preservation

Reducing Emissions

Sector	Methods of Reducing Emissions
Energy Supply	Nuclear power, renewable energy methods, carbon capture and storage
Transport	Fuel efficient vehicles, hybrid vehicles, shifts from road transport to rail and public transit systems, cycling, walking, better land-use planning
Buildings	Efficient lighting, efficient appliances, and air conditioning, improved insulation, solar heating
Agriculture	Land management to increase carbon storage, restoration of degraded lands, improved rice cultivation techniques, improved nitrogen fertilizer application
Forests	Reforestation, forest management, reduced deforestation
Waste	Composting, recycling

Agricultural Ecosystems
- Highly susceptible to failure
- Require an enormous demand for chemicals

Waste Disposal
- Landfills
    - Produce methane
    - Create contaminated landscapes
    - Negatively impact surrounding land
- Incineration
    - A major source of air pollution
    - Release of toxins
- A study in England showed that if all domestic waste was incinerated instead of land filled, the net annual emission reduction would be 5% of total England greenhouse emissions

Carbon Sequestration
- This is the use of technology to capture and store carbon dioxide to keep it out of the atmosphere
- Issues:
    - Cost of implementation
    - Finding a location to store CO2
    - It provides an excuse for not switching to renewable energy
    - The technology is not in place in many locations

Solar Energy
- Photovoltaics convert light directly to electricity

Wind Energy
- Over 30 GW of power are generated globally each year
- Each turbine can generate up to 6MW
- The location of a turbine is crucial to maximize the production of electricity
- Turbines need a back-up generator when wind is light
- Costs are becoming competitive with fossil fuel plants
- In Ontario, we don't have any area that is entirely reliable on wind power
- Wind farms are viable in areas with constant, moderate winds
- Issues preventing the growth of wind farms:
    - Cost
    - Noise
    - Habitat disruption
    - Appearance (NIMBYism)
- NIMBY → Not In My Back Yard → The person may support the building and development of these things as long as they are no where near where the person lives or can see it

Wind Energy In Ontario

- Ontario is committed to funding wind energy and has created a wind atlas to identify possible locations for future sites
- Best place to build is near Lake Erie or Lake Huron
- Flat, open landscapes are the best place for wind farms

Hydroelectric Energy

- The largest current project is the Three Gorges Dam on the Yangtze River in China
- Globally, hydroelectric power could generate 3-4 times more power than it does currently
- As the water goes through the dam, it spins the turbine and runs the generator
- The landscape behind the river will be flooded; cannot be built in an urbanized area
- Implications of large projects:
    - Loss of land to flooding
    - Displaced population
    - Leaching
    - Destruction of habitats
- Small generators on smaller rivers are more desirable but can be very costly