# Gardening in a Changing Climate

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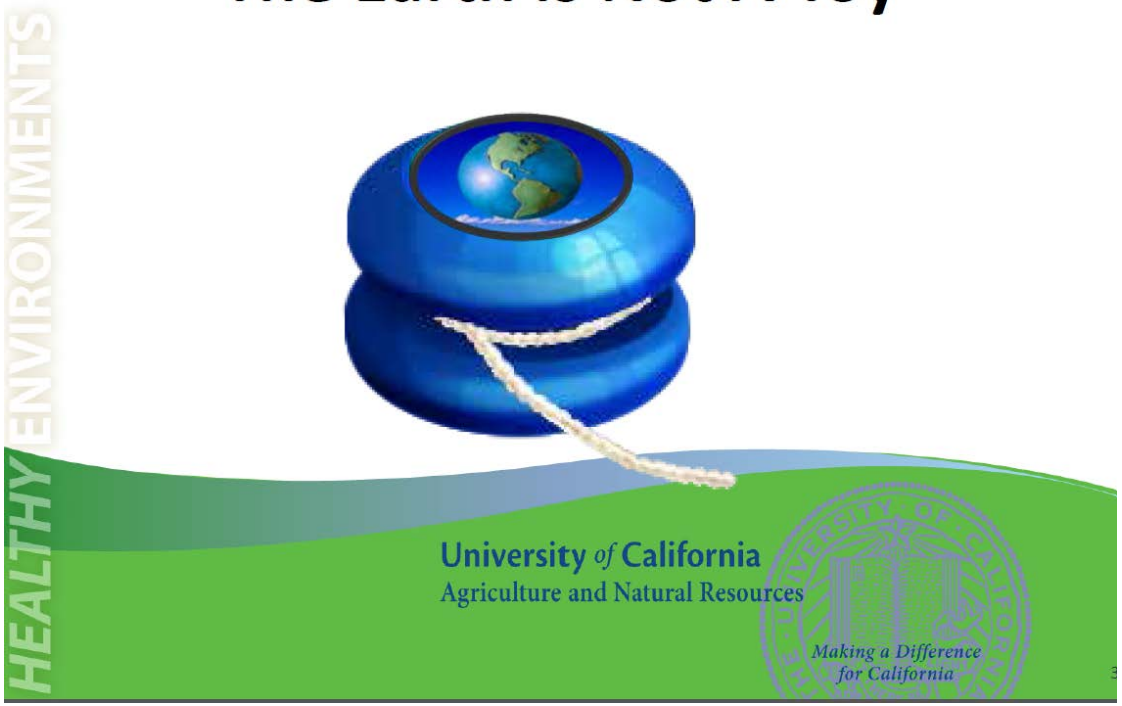
## "Advice to Grow By … Ask Us!"

Master Gardeners are trained volunteers who share knowledge and skills with the public.

Master Gardeners teach research-based information on home horticulture, pest management, and sustainable landscape practices.

# The Earth is Not A Toy



# Treat It As If Were Your Home


Because…
IT IS !

# Outline

I. Introduction
II. Climate Controlling Processes
III. Mass Extinctions
IV. Comparing Mass Extinctions to Today
V. Human Influences
VI. The Consequences of Proceeding as Usual
VII. What Can Be Done

# I. Introduction

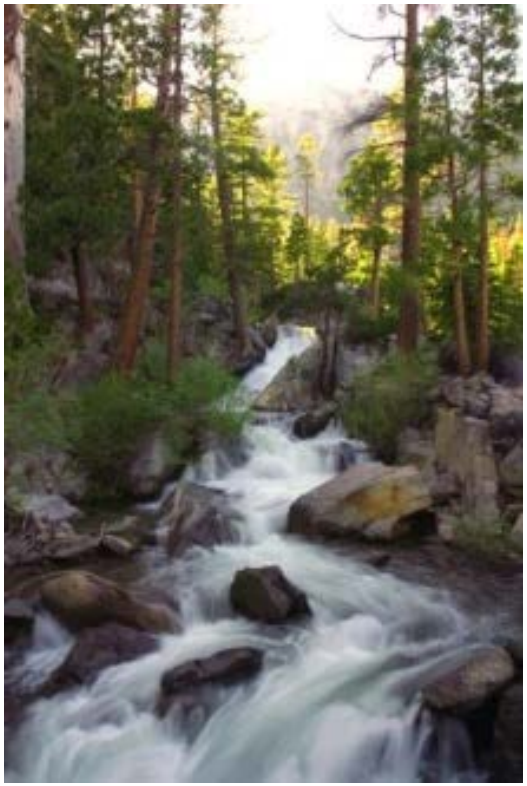
- Comments on where we are going
- Life's essentials

# Introduction

Life's Essentials (1)

Elements critical to life on earth

- Energy
- Water
- Certain Chemical Elements
- Critical Temperature
- Atmospheric Composition



# Introduction Life's Essentials

**Energy**

- Sun
- Chemical Reactions

**Water**

- Dissolves
- Transports
- Formation of Cell Walls

**Elements**

- Carbon
- Oxygen
- Hydrogen
- Phosphorous
- Sulfur

# Introduction

## Life's Essentials

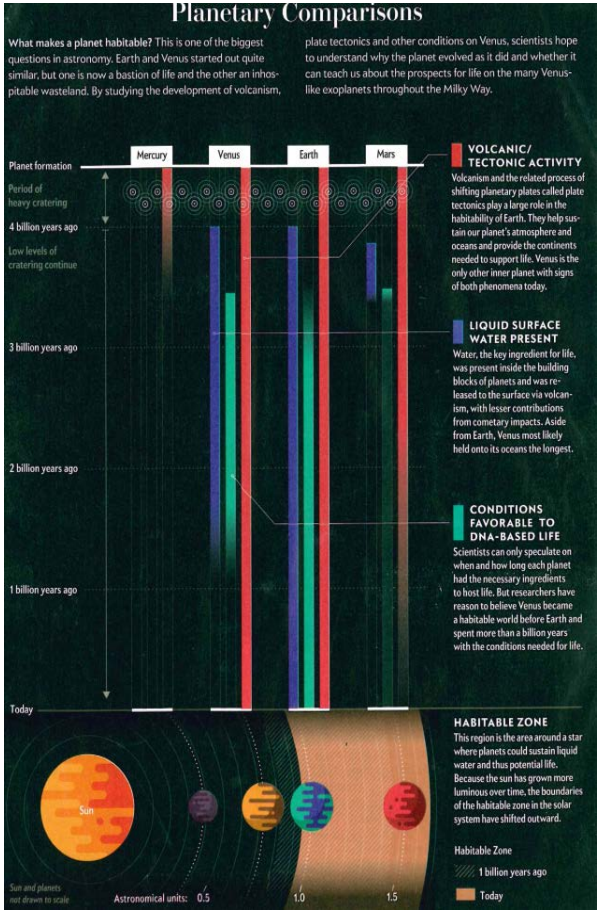
**Critical temperature**

- Liquid water
- Habitable Zone

**Atmosphere**

- Green House effect ($CO_2$)
- Albedo

(Earth's reflectance of sunlight)



# II. Climate Controlling Processes

**Earths climate is primarily controlled by the amount of carbon dioxide in the atmosphere.**

**These natural processes control the $CO_2$ concentration.**

- Plate tectonics
- Volcanism
- Rock Cycle
- Formation and break up of continents
- Photosynthesis
- Earths orbit is also a contributing factor

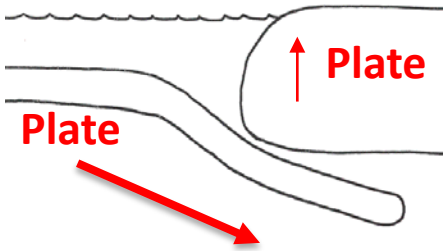
# Climate Controlling Processes

## Plate tectonics

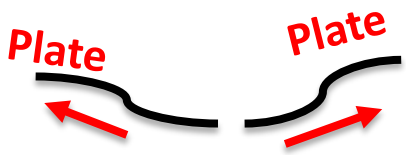
- Initial molten Surface
- Cooling forms crust
- Crust cracks into large slabs as it cools
- Think sea ice

  Pressure ridges = Mountain ranges

  Open leads = Rift Valleys
- Molten mantel moves crustal plates around
- Subduction and rifts




Subduction

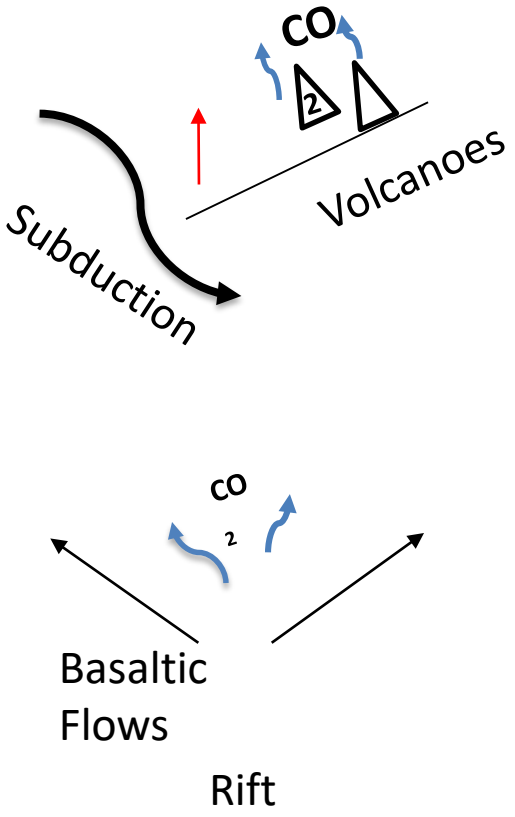



Rift

# Climate Controlling Processes

## Volcanism

- Subduction yields strato-volcanoes
- Rifts yield shield volcanoes or continental basaltic flows
- Lava released contains dissolved $CO_2$ under pressure
- Released lava reduces pressure and releases CO2 into the atmosphere
- Volcanism primary natural source of $CO_2$ in atmosphere



# Climate Controlling Processes

## Rock Cycle: Earth's natural thermostat (weathering)

Heat in the deep earth melts the rock releasing $CO_2$.

Plate Tectonics create volcanoes and hydro-thermal vents.

Volcanoes and hydro-thermal vents release $CO_2$ into the atmosphere.

$CO_2$ and rainwater combine to break down rock, create carbonate and store $CO_2$ in sediment that is washed into the ocean. Called Weathering.

Sedimentary rock containing carbonate is subducted by plate tectonics.

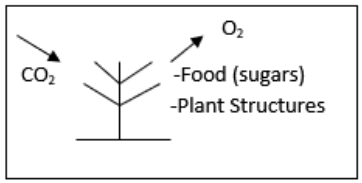
Weathering reaction is faster with higher atmospheric temperatures and slower with colder temperatures.

# Climate Controlling Processes

## Short Term Carbon Cycle

### Photosynthesis

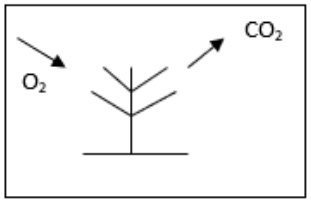
(Day only)




- Food (sugars)
- Releases oxygen to atmosphere

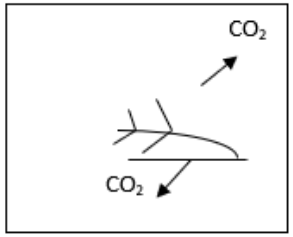
### Respiration

(Day & Night)




-Combine sugars and oxygen
-Produce every plant material
-Release $CO_2$ to atmosphere

### Decomposition




-Decomposition releases CO2 to atmosphere
-Some carbon in soil
-Some carbon sequestered in rock, as coal

# Climate Controlling Processes

## Human Interactions

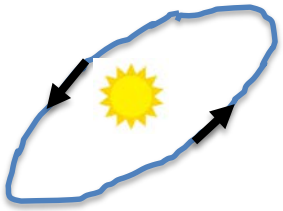
What about human $CO_2$ additions to the atmosphere?

- Increasing $CO_2$ levels will/ are causing warming
- Warming will cause more rain and more weathering
- $CO_2$ levels will fall
- Temperatures will remain constant or fall
- What's the problem?
- Yes BUT not so fast…!

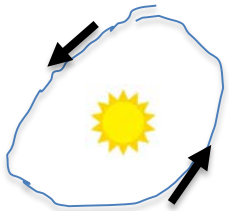
# Climate Controlling Processes

## Earth's Orbit

- Orbital impact on climate (Milankovitch cycles)
- Eccentricity



Orbit more elliptical



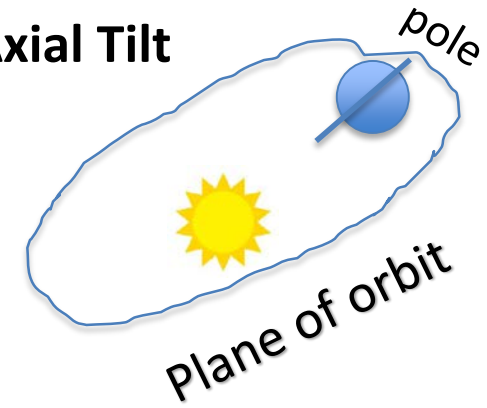
Less Elliptical

100,000 Year Period

# Climate Controlling Processes

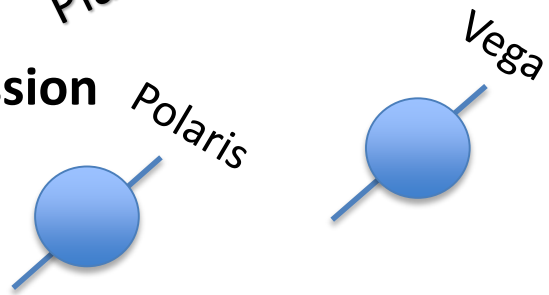
## Earths Orbit cont.

**Axial Tilt**




41,000 Year Period

**Precession**

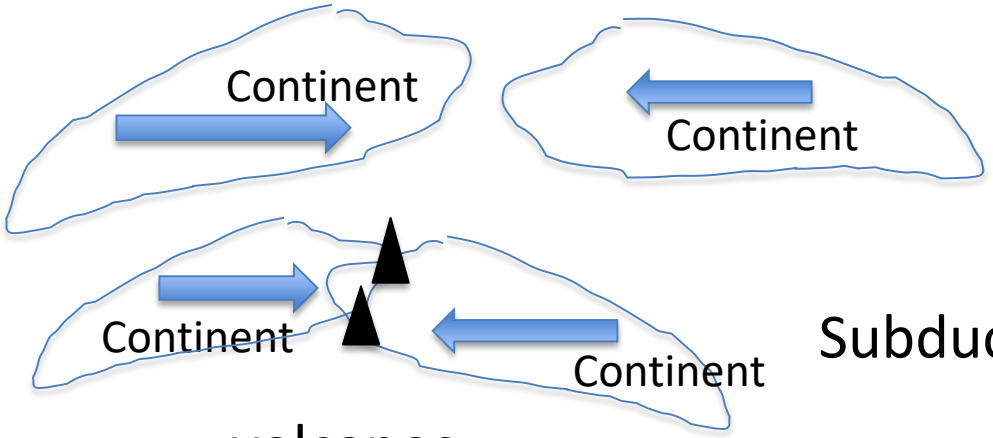



23,000 Year Period

# Climate Controlling Processes

Supercontinents

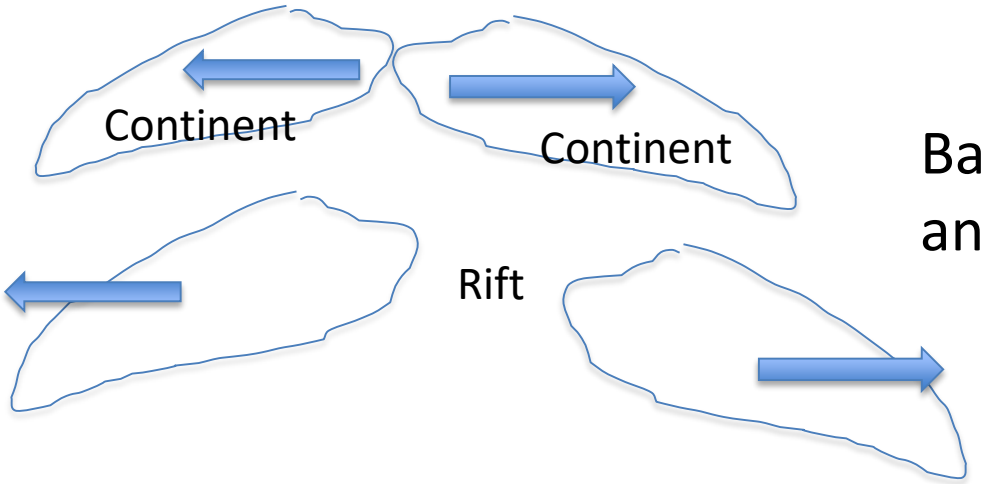
- Similar to Plate Tectonics
- Continents collide to form supercontinents




Subduction and uplifting

# Climate Controlling Processes

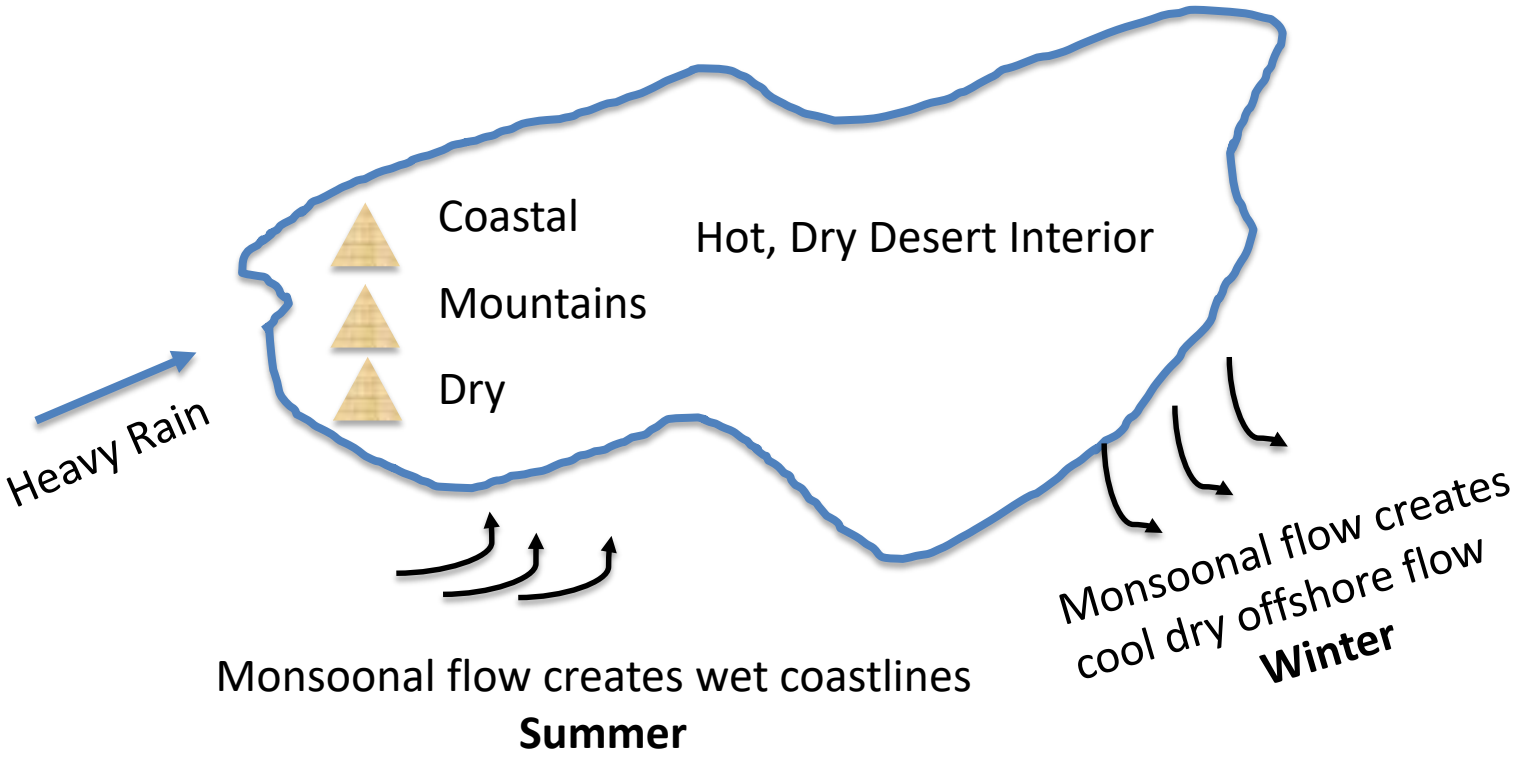
Supercontinents break up



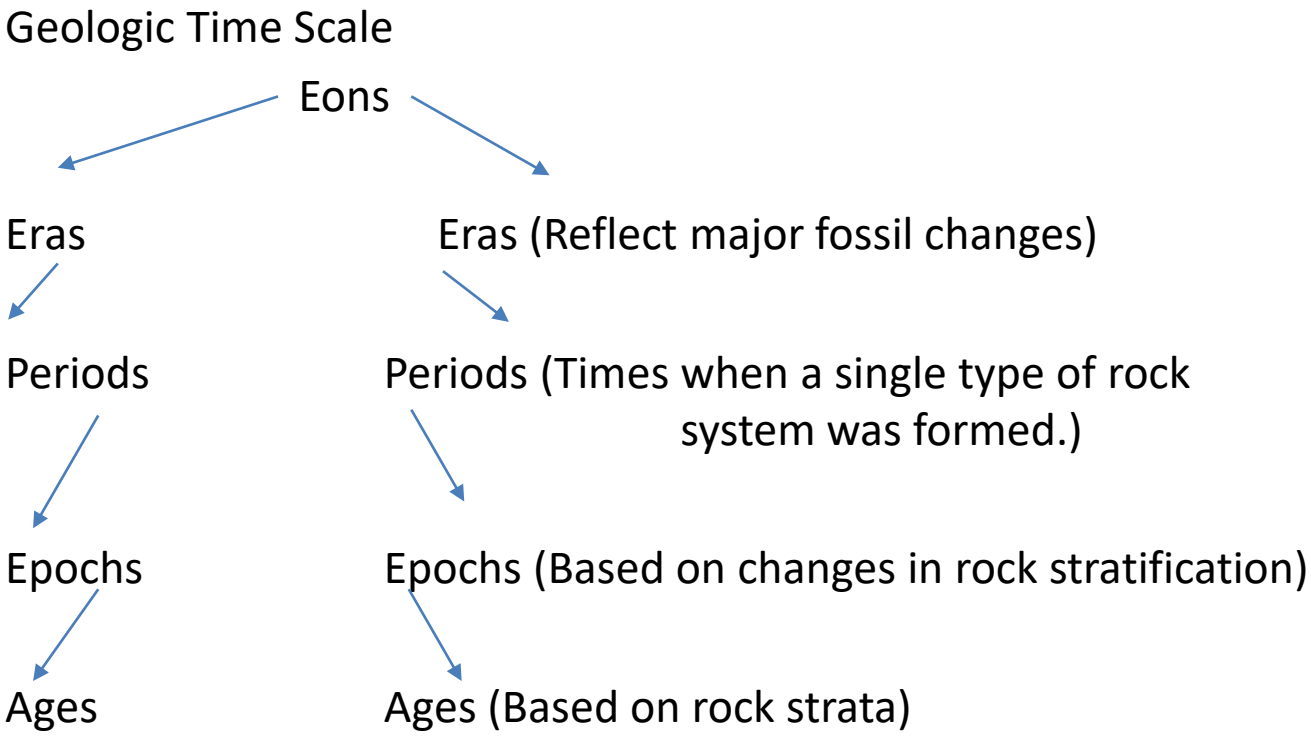

Basaltic flows and volcanos

# Climate Controlling Processes

Supercontinents climate modification



# III. Mass Extinctions



# Mass Extinctions
# Phanerozoic Eon to Present Day

**Paleozoic Era**
**542-252 MYA**

- Cambrian Period
  542-486
- Ordovcian Period *
  486- 443
- Sillarian Period
  443-419
- Devonian Period *
  419- 359
- Carboniferous
  Period
  359- 299
- Permian Period *
  299- 252

**Mesozoic Era**
**252- 66 MYA**

- Triassic period *
  252- 199
- Jurassic Period
  199- 145
- Cretaceous Period *
  145-66

**Cenazoic Era**
**66 MYA to present**

- Paleogene Period
  66-23
- Neogene Period
  23-1.8
- Quartenary Period
  1.8 to present day
- Anthropocene?

***Denotes mass extinctions**

# Mass Extinctions (7)

- Definition- When more than half of the earth's species go extinct in fewer than one million years.
- Most happen much more quickly.
- Some occur in only a few thousand years.
- Five extinctions in earth's 500-million-year history of life
  - Late Ordovcian Period 445 million years ago
  - Late Devonian Period 374 million years ago
  - End Permian Period 252 million years ago
  - End Triassic Period 201 million years ago
  - End Cretaceous Period 66 million years ago

# Mass Extinctions

## Causes

- $CO_2$ is the driver of mass extinctions
  - Large $CO_2$ fluxuations disrupt rock cycle
  - Rock cycle disruption impairs $CO_2$ balance
- Causal Factors
  - One from asteroid impact (cretaceous)
  - Remaining four from climate and ocean changes driven by geologic forces
  - Earliest two (Ordovician & Devonian) may have been due to lack of $CO_2$ locking earth in ice
  - Biggest three in last 300 million years (Permian, Triassic, Cretaceous) from high $CO_2$

**The earth has run the $CO_2$ experiment many times in the past. It has <u>always</u> ended badly.**


25

# Mass Extinctions

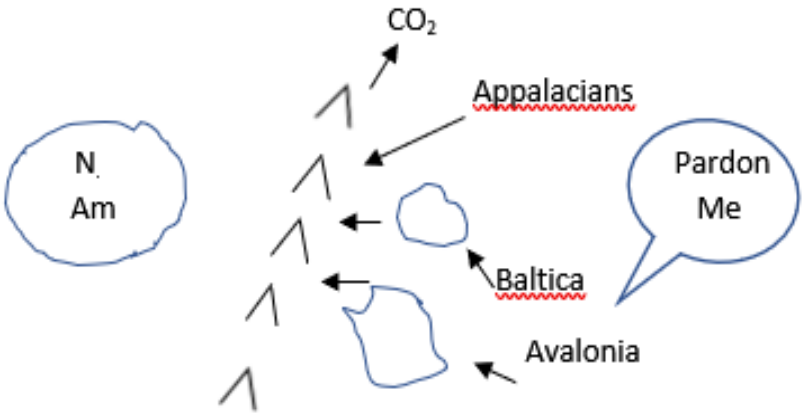
Two other extinctions (7)

- 490 MYA in the Cambrian period
- 55 MYA in the Paleogene period
- The first resulted from biological processes.
- The second from warming and acid/ anoxic seas.
- Neither rose to the level of mass extinction.

# Mass Extinctions

## Late Ordovician Extinction – 445 MYA (7)

- Period known as the "Great Ordovician Biodiversification Event"
- Period ended with almost all species wiped out (85%)
  - Second worst extinction event in last 500 MYA
  - Little life left on land or sea
- Caused by onset of an ice age
- What went wrong?
- Consequences
- Parallels for today



# Mass Extinctions

## Late Devonian Extinction – 374 MYA (7)

- Period known as the age of fish
- Extinction occurred in two phases
  - Phase I – 374 MYA
    - Reefs destroyed
    - Huge plankton blooms
    - Seas anoxic
    - Mass die offs
  - Phase II – 359 MYA
    - Anoxic seas increase
    - Top predators killed off
- 99% of reef systems destroyed
- Worst extinction for vertebrates ever 96%
- What went wrong?
- Consequences
- Parallels for today

# Mass Extinctions

End of Permian Extinction – 252 MYA (7)

- Greatest mass extinction in earth's history
- 95% of marine species extinct
- 70% land species extinct
- Prior to the extinction
- Post extinction
- What Caused it
- What went wrong
- Consequences
- Parallels for today

# Mass Extinctions

## Some points to ponder

"CO2 emissions appear to be the driver of extinctions throughout earth's history. CO2 driven global warming is not just being simulated in computer driven models, but it is an experiment the earth has run many times before, including the Permian Extinction. Is it happening again? Many scientists think so." Peter Ward, "Under a Green Sky"

"Basically, the entire modern global economy rests on how quickly we can get carbon out of the ground and put it in the atmosphere. That's basically the global enterprise. There are a lot of people doing it. Geologically, it's a really impressive effort." Andy Ridgewell

So were the Siberian eruptions.

No one knows where our modern actions of injecting green house gases into the atmosphere will lead, but in the end – Permian, it led straight to the cemetery. (7)

# Mass Extinctions

End of Triassic Extinction – 201 MYA

- Prior to extinction
- Crocodiles reign supreme
- Post extinction
  - 75% of all plants & animals become extinct
  - Coral reefs almost completely extinct for over 300,000 years
  - End of reign of crocodiles
  - Rise of dinosaurs
- What Caused it
- What went wrong
- Consequences
- Parallels for today

# Mass Extinctions

## End of Cretaceous Extinction – 66 MYA

- Prior to extinction
  - Dinosaurs ruled
- Post extinction
  - 75% of all land and sea species go extinct
  - plankton nearly vanished from fossil record
  - Mammals arise
- What caused it
- What went wrong
- Consequences
- Parallels for today

# IV. Comparing Mass Extinctions to Today

## The Deadly Chain of Events

- Rising atmosphere $CO_2$ overwhelms the rock cycle
- Atmosphere warms
- Ocean warms
- Rising ocean temperature kills some species and reduces dissolve oxygen killing more
- Ocean absorbs $CO_2$ and acidifies
- Acid rain dissolves rock washing nutrients into the ocean
- Decaying algae/ phytoplankton removes oxygen from the ocean
- Oceans become anoxic
- Melting glaciers stratify ocean worsen anoxic conditions

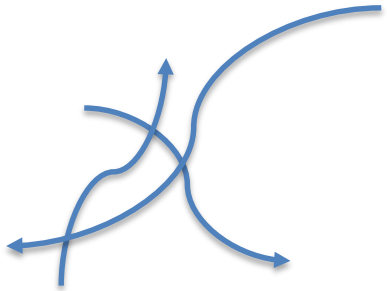
# Comparing Mass Extinctions to Today

| | High CO2 | Low Co2 | Global Warming | Ice Age | Ocean warming | Ocean Acidification | Anoxic ocean | Reef die off | Ozone depletion | Loss of speciation | Nutrient flows in seas | Ocean Stagnation | Destruction of food chain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| End Ordovician | | X | | X | | | X | | | | | X | |
| Late Devonian | | X | | X | | | X | X | | X | X | | X |
| End Permian | X | | X | | X | X | X | X | X | X | X | | X |
| End Triassic | X | | X | | X | X | X | X | | X | X | | X |
| End Cretaceous | X | | X | | X | X | | | | | | | X |
| Today | X | | X | | X | X | Some | X | X | X | X | Some | Some |

# Comparing Mass Extinctions to Today

## What about today?

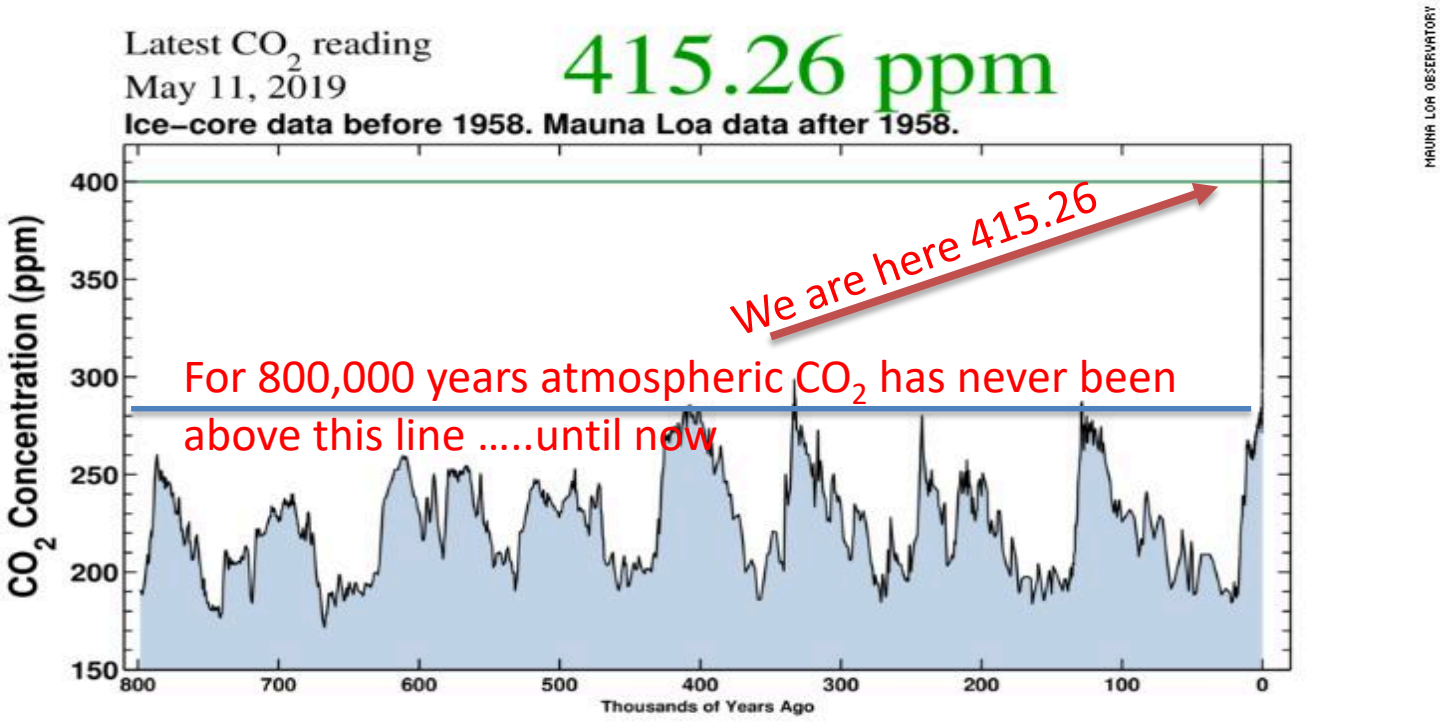
- Earth undergoing massive changes
- $CO_2$ levels rising
- Atmospheric temperature rising
- Sea levels rising
- Oceanic & atmospheric circulation patterns changing
- Ocean temperatures rising
- Ocean acidifying
- Ice is melting
- Loss of species



I don't think you are going to like this pattern…

# Comparing Mass Extinctions to Today

## What about Today?



# Comparing Mass Extinctions to Today

## Temperature vs. $CO_2$

Atmospheric CO2 Concentration

- Earth avg. temp in 2017 was 14.9$^0$C and rising
- Avg. temp was 13$^0$C prior to industrial revolution
- It was 27$^0$C in Pliocene and falling, & 26$^0$C in eocene when $CO_2$ levels were 500 & 2100 ppm respectively
-May 2019 $CO_2$ concentration was 415 ppm up 3.75 ppm from May 2018
-At current rate of increase, $CO_2$ will double from pre-industrial revolution level to 540 ppm by 2054

# Comparing Mass Extinctions to Today

## Relationship of Temperature, $CO_2$ & Sea level

The relative changes in global average temperature, $CO_2$ & sea level over the past 420,000 years

www.johnenglander.net

# Comparing Mass Extinctions to Today

## What about Today

### Ocean warming & acidification

- Ocean warming
  - Much of atmospheric heat absorbed by ocean
  - The $10^0$C conundrum
  - Coral bleaching
- Ocean acidification
  - End of ocean absorption may be near
- Consequences
  - Reef decreased 30% since early 1980's
  - Disruption of food chain
  - Extinctions

# V. Human Influences

Mid-latitude deforestation

Rain  forest destruction

Industrial revolution

Rise in modern transportation

Burning of hydrocarbons

Disruption of nitrogen cycle

Agricultural run off

Inverting vertebrate life

Loss of speciation caused by humans

# Human Influences
## Are we in a Mass Extinction?

- Are we in a mass extinction now?
- All is not lost
- So… What's to worry about?
- Or is it? Tipping points & such
- Everything is fine until it isn't
- We have time, but not much

# VI. The Consequences of proceeding as Usual

- The problem (7)
- Human development & the future
- Increasing atmospheric CO2 & warming
- Ocean warming
- Ocean acidification (16)
- Destruction of reef ecosystem (17)
- Deglaciation (8, 9, 10)
- Melting permafrost
- Rivers running dry due to loss of glaciers
- Increased desertification
- Rise of sea level
- Changes in global atmospheric circulation (15)
- Changes in ocean currents (13)
- Changes in cloud distribution (12)
- Wet bulb conundrum
- Species extinction (14)
- Local consequences (11)

# The Consequences of Proceeding as Usual

2015 Paris climate accords (7) (23)

- Provisions
  - -Attempts to limit global temperature increase
  - -Non-Binding
  - -Won't prevent $2^0$C temperature increase
  - -Only about 5 years of $CO_2$ emissions left
  - -Doesn't stop warming post 2100
  - -Is there political will
  - -Steps needed to limit temperature increase
  - -What happens if we don't fix it

# The Consequences of Proceeding as Usual

(How Climate Change can Affect Life, an Object Lesson)

The Viking settlement of Greenland
- Settlement began about 1000
- Two colonies
- Settled during Medieval warming period (950 – 1250AD)
- Colonies disappeared in mid-1400's
- Little Ice Age about 1250-1850
- Settlement lasted (though declining) about 200 years after start of little ice age
- Little Ice Age only one factor in collapse, others
    --- Ivory trade collapse
    --- Fur trade collapse
    --- Black plaque occurred in Europe
    --- Invasion of Native Peoples

# VII. What Can Be Done

- Governmental Actions
- Individual Actions
- Technology on the horizon

# What Can Be Done

## Governmental Actions

-Let nature solve the problem *
-Move from fossil fuels to renewable energy
-Responsible forestry & water use practices
-Preserve/create wetlands
-Increase electrification of transportation
-Cap & trade

*The Nature Conservancy Magazine. Fall 2018
The Green Path to a Stable Climate.

# What Can Be Done

## Governmental Actions

-Cap and Trade (The California Model) *
-What is it
    --Limits overall greenhouse gas emissions
    --Credits given to industry
    --Credits can be sold
    --Credits reduced each year
-What is its impact
    --Not limited to California
    --Catalyzing Forest Conservation Programs
    --Encourages better forest management
    --Results so far
-Is There a Better Way
    --The problem with Cap & Trade and Carbon Tax

*The Nature Conservancy Magazine. Winter 2017
Brandon Borrell. The California Effect.

# What Can Be Done

## Individual Actions

- Facing the coming changes
- Changes in frost free season lengths
- Dryland Farming
- Regenerative Agriculture
- Conservation Agriculture
- Tree intercropping and wind breaks
- Plant an urban forest
- Sustainable intensification
- Responsible use of fertilizer
- Rain gardening, basins, drywells
- Plant deep rooted or woody plants
- Irrigation techniques
- Composting vs. landfill

# What Can Be Done

## Individual Actions

- Managed grazing
- Reduce food waste
- Adopt plant rich diet
- Source food locally
- Solar energy
- Electric vehicles
- Building insulation
- LED lights in household
- Solar hot water
- Smart thermostats
- Smart window glass
- Switch detergents
- Call/meet your representative
- Get involved in dialogue
- Find common ground
- Volunteer in your community

https://www.drawdown.org/solutions-summary-by-rank

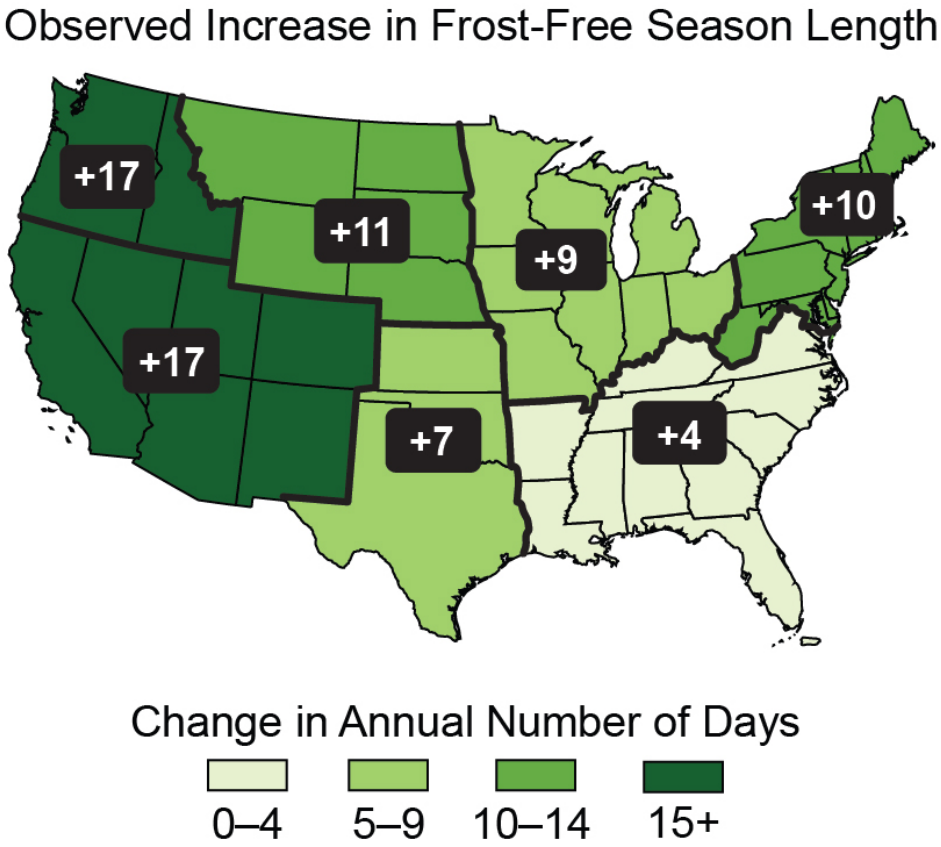
# What Can Be Done

## Individual Actions

Facing the Coming Changes

- Climate zones moving north to higher elevations
- Lengthening of growing season
- Animals moving north or higher
- Earlier migrations
- Impact in our area
  - Climate similar to Tucson or Phoenix (13)
  - Hotter and drier
  - Rainfall variable
  - Chilling Hours Changes

# What Can Be Done




Source: Climate Science Special Report: Fourth National Climate Assessment, Volume I

# What Can Be Done
## Individual Actions

Dry land farming *

- What is it
- What can I grow
- Techniques
  - Conserve and use water effectively
  - Reduce Evapotranspiration
  - Improve soils ability to hold and absorb water
  - Reduce or prevent run off
  - Maximize rainfall storage
  - Plant quick maturing trees (or dwarf varieties)
  - Control wind and heat
  - Reduce weeds
  - Select dry land crops
  - Plant fewer plants farther apart
  - Alternate fallow beds

- Dryland farming: crops & techniques for arid regions. Randy Creswell & Dr. Franklin W. Martin. 1993 Wikipedia. Calif. Ag Water Stewardship Initiative.

# What Can Be Done

## Individual Actions

Regenerative Agriculture

- What are healthy soils?
- What do they do?
- What practices create healthy soil?
- What can you do?
- What is the Climate effect?

Conservation Agriculture

- Basically it's no-till agriculture
- Three principals
- Climate effect
  - If used- it could sequester ½ ton carbon per acre per year.


Nature conservancy magazine. Spring 2018. Amy Crawford and Larry Clemens. Seeds of Change.

# What Can Be Done

## Individual Actions

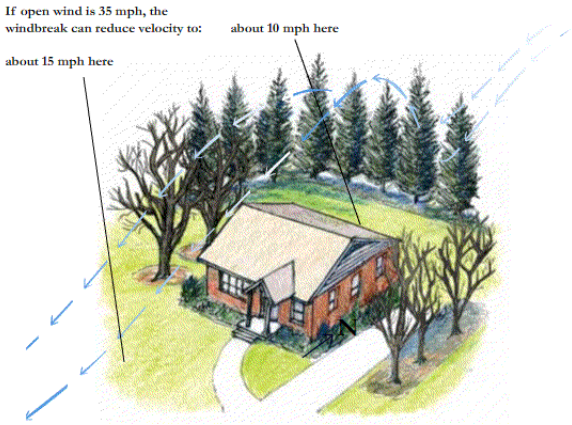
Tree intercropping and wind breaks *

- What is it?
- Benefits of intercropping
- Benefits of homestead windbreak
- Climate effect

Plant an urban forest

Sustainable Intensification **

- What is it?
- What does it do?
- What are the requirements?
- Climate connection?




* Drawdown.org

** Nature conservancy Magazine. Spring 2018. Matt Jenkins. Smart Growth.

# What Can Be Done

## Individual Actions

Responsible use of fertilizer

- Apply responsibly
- Consequences of over application

Rain Gardening, basins & dry wells

- Slow run off
- Increase soak in
- Recharge aquifers

Plant deep-rooted plants *

- Removes more CO2 from the atmosphere
- Stores carbon deeper in soil

* Drawdown.org

Irrigation Techniques

- Drip
- Irrigation scheduling
- Deficit irrigation

# What Can Be Done

## Individual Actions

Irrigation Techniques

Composting vs Landfill

- A rich source of soil amendments
- Reduces methane emissions

Managed grazing

- Managed grazing techniques
- Climate benefits (*sequesters .5 – 3 tons carbon per acre)

Reduce food waste

- Magnitude of the problem
- Consequences
- Climate benefits of reducing waste (*reducing food waste 50% by 2050 = $CO_2$ reduction of 26.2 gigatons)

* Drawdown.org

# What Can Be Done
## Individual Actions

Adopt a plant rich diet

- Beef production produces a lot of greenhouse gasses
- Benefits of switching

Sourcing food locally

- Less fossil fuel used for transportation
- Plant less water intensive foods in home garden

# What Can Be Done

## Individual Actions

Roof top solar (Photovoltaics)

- Falling prices
- Becoming competitive with conventional power
- Climate benefits

Electric vehicles

- Emission reduction
- Climate benefits

Building insulation

- The problem
- Impact of improved insulation

# What Can Be Done
## Individual Actions

- Household LED lights
  - Energy savings of household LED's (90% less energy)
  - Emission reduction
- Solar hot water
  - Solar hot water reduces fuel consumption by 50%-70%
- Smart thermostats
- Smart window glass
- Switch detergent choice to cold water types
- Stop using one use bottles and straws

# What Can Be Done

## Individual Actions

- Call or meet with representatives
- Open dialogue / seek common ground
- Volunteer in your community

# What Can Be Done

## Technology

- Drawing water from the air
- Fuel and fertilizer from leaves
- Sustainable communities

# What Can Be Done

## Technology *

Drawing water from the air

- Works even in low humidity
- Uses sun to operate
- Efficient

Fuel and fertilizer from leaves

- Artificial photosynthesis
- More efficient than natural leaves
- Splits water into hydrogen and oxygen

Sustainable communities

- Solar power production near area of use
- Concentrate solar panels
- Store excess power and use as needed
- Reduce CO2 emissions

* Scientific American. Dec. 2017. Top 10 Engineering Technologies.

# CLOSING

- The earth has run the $CO_2$ experiment many times. It has never ended well.
- Everything is fine. Until it isn't.
- Are we there?
- Three choices
  - Suffer
  - Adapt
  - Mitigate
- OR…
- It's our choice

# CLOSING

## AND A LAST THOUGHT

The difference between a sustainable future & a deadly collapse is largely dependent on a population's forethought – How soon they realize they are destroying their planet, and how quickly they take action.

Winners - Manage to see what is going on and figure out a path through it.

Losers - Just can't get their act together, and their civilization falls by the wayside.

The Question is, which category do we want to be in….

Adam Frank, Professor of Physics & Astronomy, University of Rochester, New York.

# CLOSING

Thank you for the privilege of your time

Questions

Presentations & Text can be found at

http://mgeldorado.ucanr.edu/Public_Education_Classes/Handouts_-_Presentations/

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