Terrestrial Ecosystem Response to Climate Change

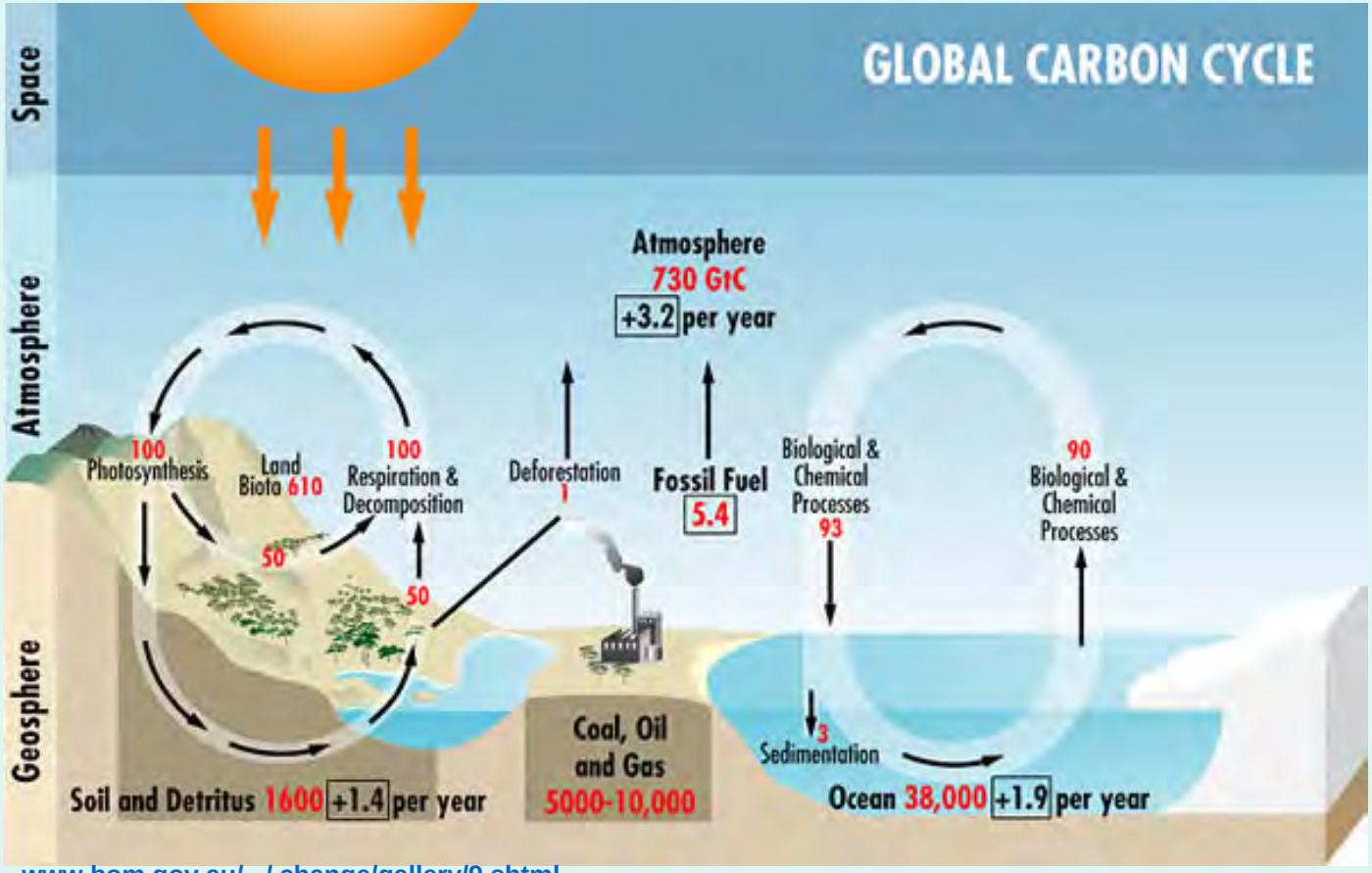
Global Change and Effects on Terrestrial Ecosystem

Introduction

- Temperature, precipitation, latitude and altitude all determine distribution of major terrestrial ecosystems (biomes).
- Plants found within the different biomes are influenced by soil type, water shed conditions and amount of sun.
- Specific combinations of temperatures and precipitation ensure the survival and thriving of plants within a given environment (known as **Climate space**).

Terrestrial Ecosystems are an…

- Integral part of global carbon system
- Plants take in and store carbon dioxide from the atmosphere through photosynthesis
- Below ground microbes decompose organic matter and release organic carbon back into the atmosphere



www.bom.gov.au/.../ change/gallery/9.shtml

Cycle shows how nature's sources of CO_2 are self regulating – that which is released will be used again – Anthropogenic carbon not part of natures cycle – is in excess

Forests

- Forests occupy major portions of land mass in different countries.
  - In the U.S. forests occupy 33% of the land mass
- Forests have many functions:
  - Provides habitat for plants and animals
  - Influence amount of and availability of water runoff
  - Provide sites for recreation
  - Provide timber for harvesting lumber; wood pulp, fire wood for fuel
  - Total commercial valued in U.S. = $290 billion

Land Formation

- 18,000 years ago glaciers retreated in the Northern hemisphere resulting in a rocky and lifeless ecosystem

- Pioneer plants emerged
  - Lichens – broke down rock
  - Decaying lichens mixed with broken rock chips developed soil (long/slow process)

- Winds blew – soil flew – dispersed into crevices of rocks – provided nutrients for small plants to grow

- Soon mosses appeared followed by grasses, then larger plants (shrubs & trees) known as **primary succession**

Succession and Climax Forests

- **Primary succession** - How temperate forests first emerged
- As forests continue to grow – become more diverse in both plant and animal life
- Simple plants unable to compete – live in the shade of larger plants
- Saplings unable to develop due to shade - slowly die out (Birch, Aspen) – gives rise to **middle stage succession**
- Shade tolerant plants emerge (Maple, Hemlock) and dominate forests – now have a **climax forest**

Secondary Succession

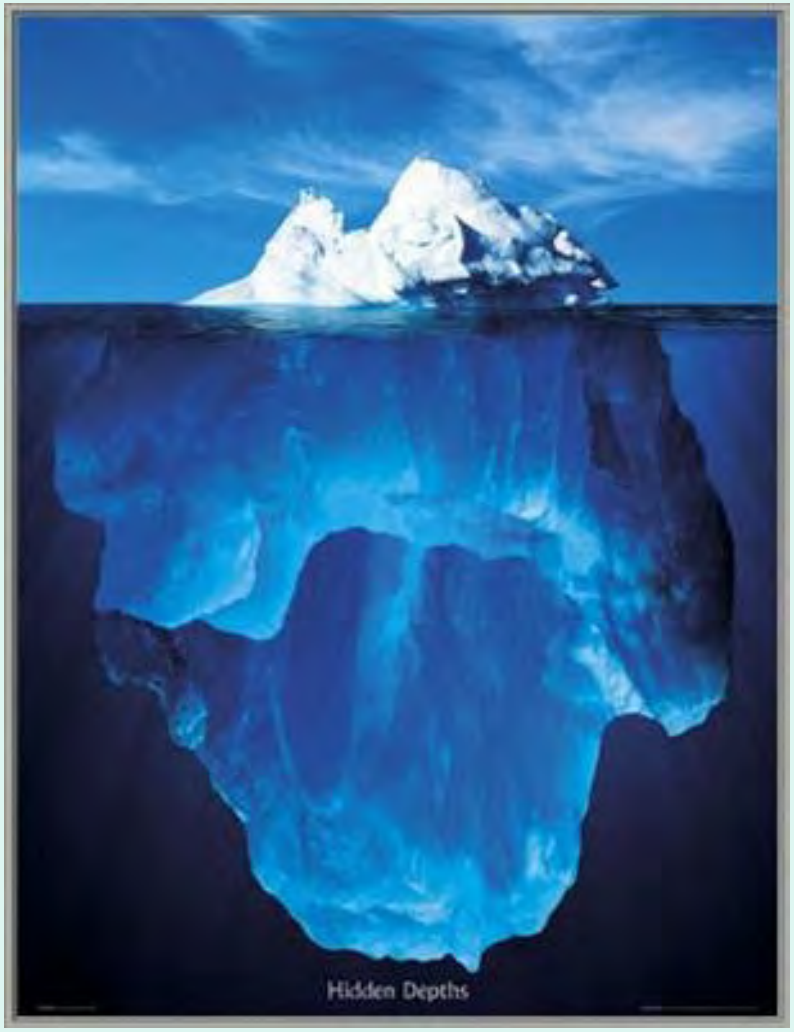
- Secondary succession occurs quicker than primary succession (soils already there)
  - Exception to this – land cleared for development and agriculture
- Temperate forests dominate because of their resistance to fires
- Less resistant trees eventually die off – leaving the evergreens still standing
- Fires promote evergreen growth by busting seed coats open and scattering them in the soil
- Deciduous forest devastated by fires
- Secondary succession only way new forest will dominate

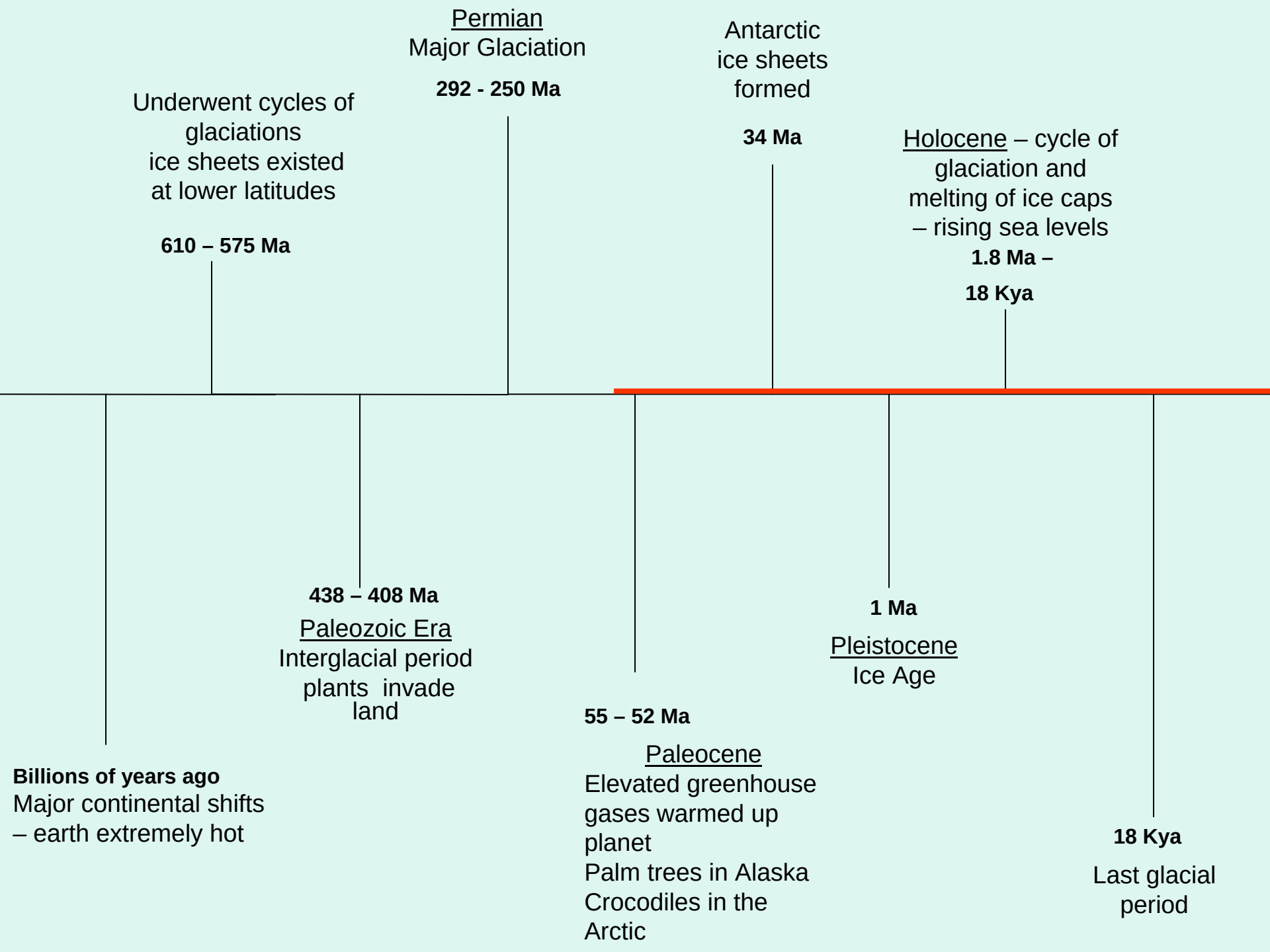
people.eku.edu/ritchisong/ secondarysuccession

A look back into time…..

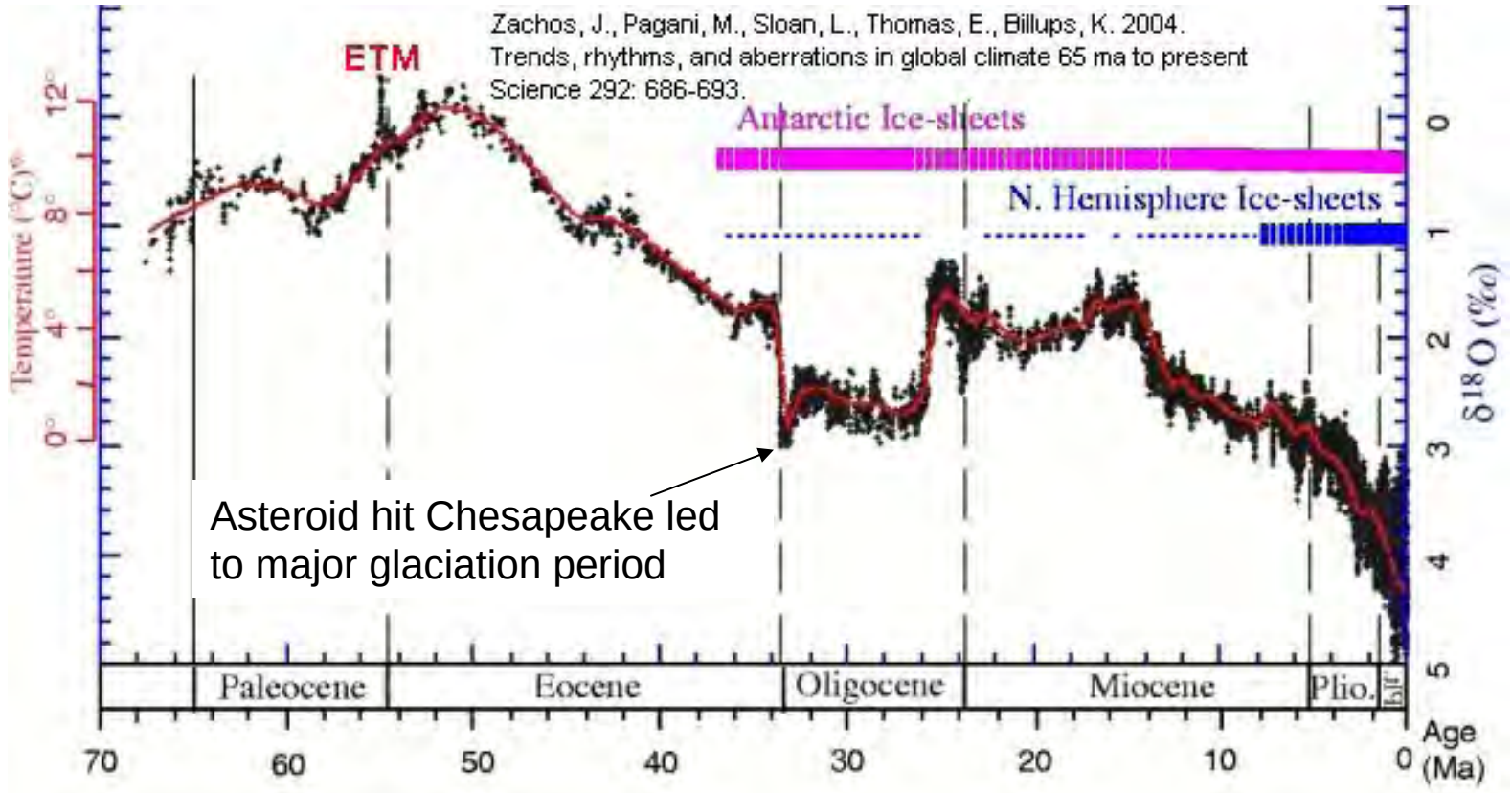
Driving forces effecting global temperature;

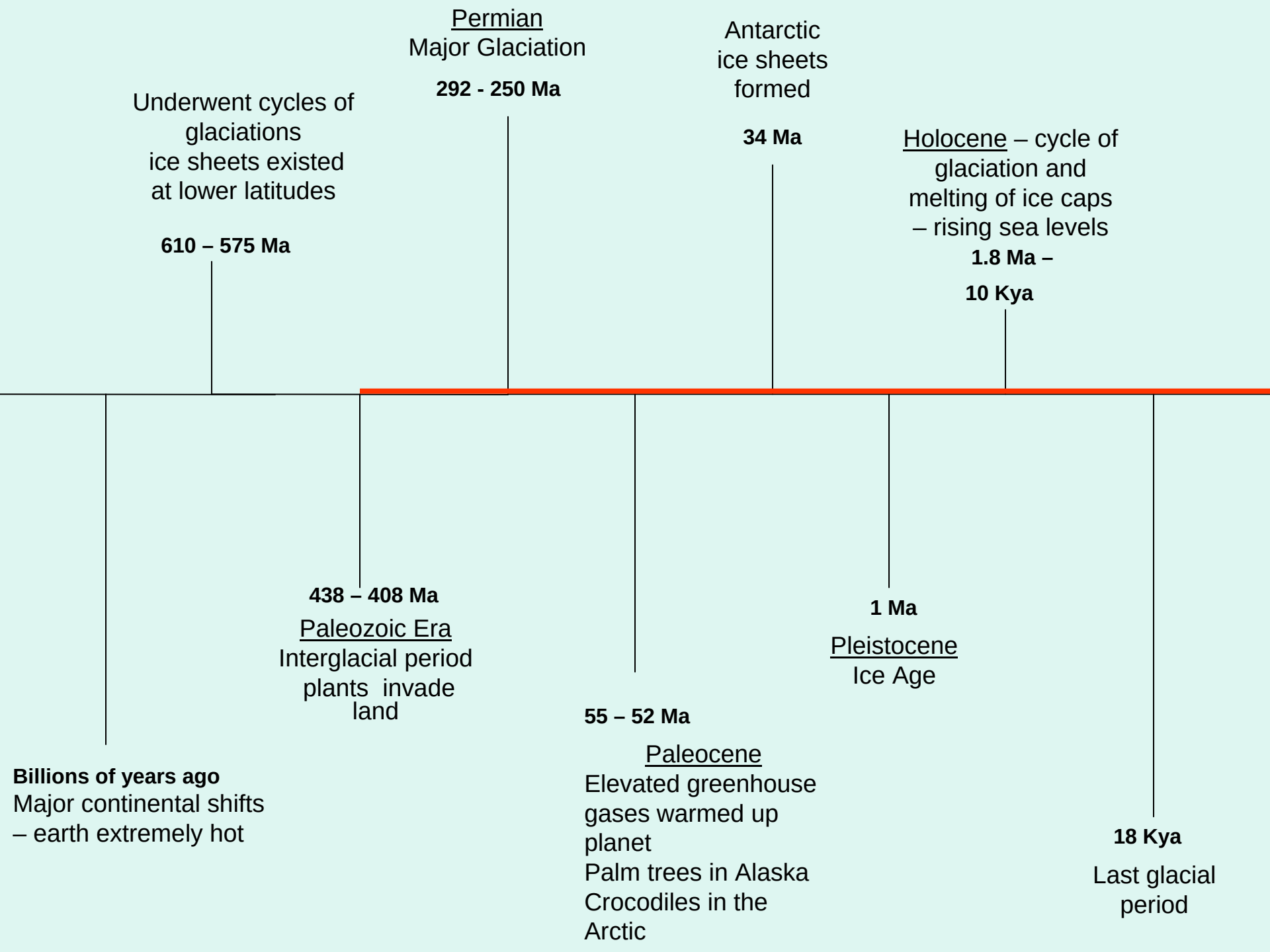
- Plate tectonics
- Earths orbital geometry (eccentricity, obliquity and precession)




Permian
Major Glaciation
292 - 250 Ma
Antarctic ice sheets formed
34 Ma
Underwent cycles of glaciations ice sheets existed at lower latitudes
610 – 575 Ma
Holocene – cycle of glaciation and melting of ice caps – rising sea levels
1.8 Ma –
18 Kya
438 – 408 Ma
Paleozoic Era
Interglacial period plants invade land
1 Ma
Pleistocene
Ice Age
55 – 52 Ma
Paleocene
Elevated greenhouse gases warmed up planet
Palm trees in Alaska
Crocodiles in the Arctic
18 Kya
Last glacial period
Billions of years ago
Major continental shifts – earth extremely hot

Changes in Global Climate 65 ma to Present

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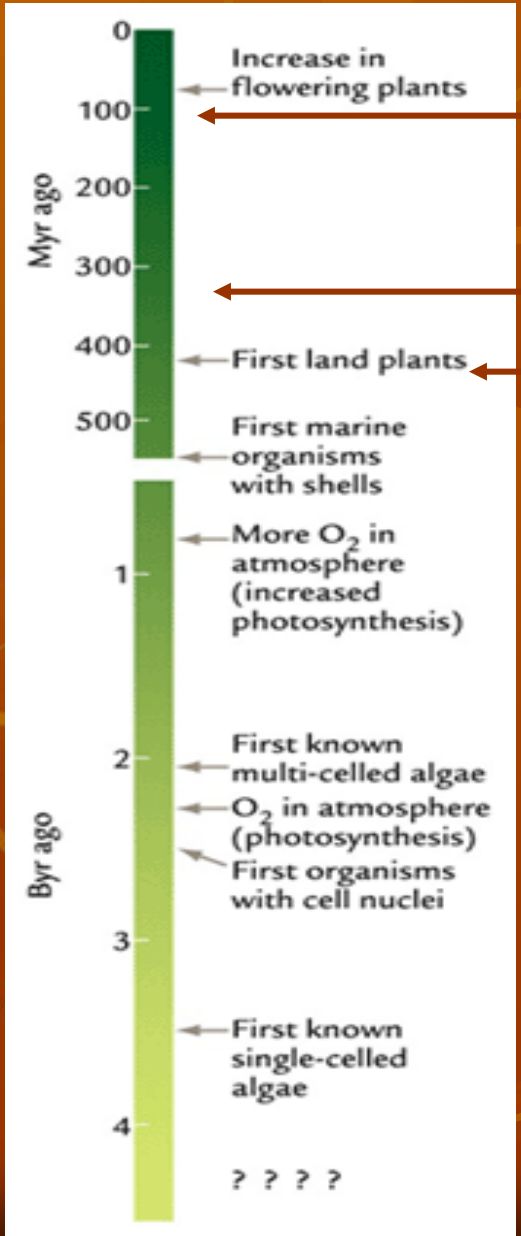
Time Line of Plant Life

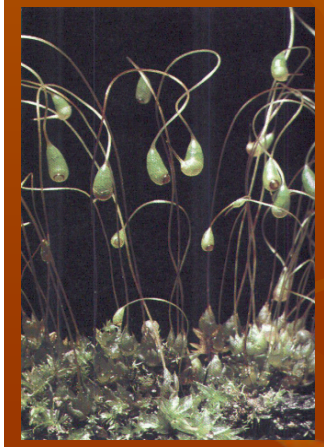


Cretaceous era (110 Ma)
Angiosperms dominate

Carboniferous (360 – 286 Ma)
Ferns, Gymnosperms

Paleozoic era (438 – 408 Ma)
Bryophytes

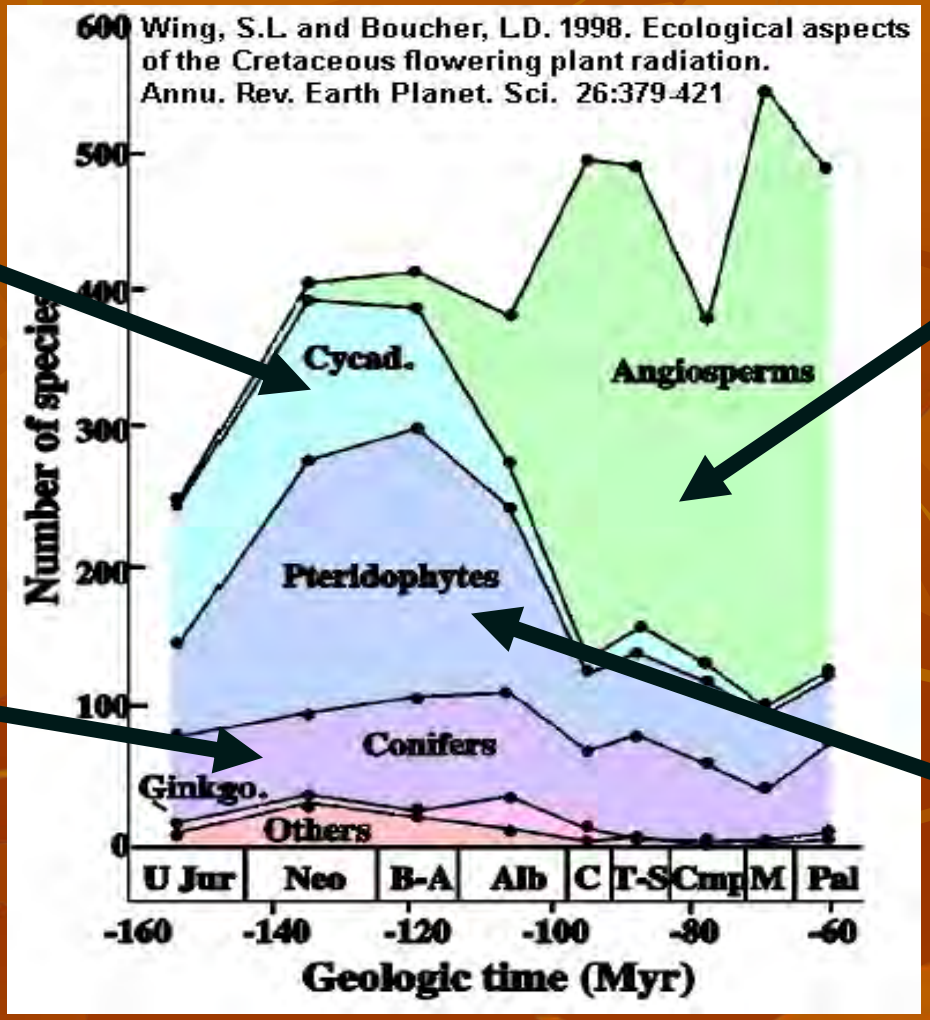
Mosses



Liverworts

Hornworts

taggart.glg.msu.edu/isb200/fland.htm



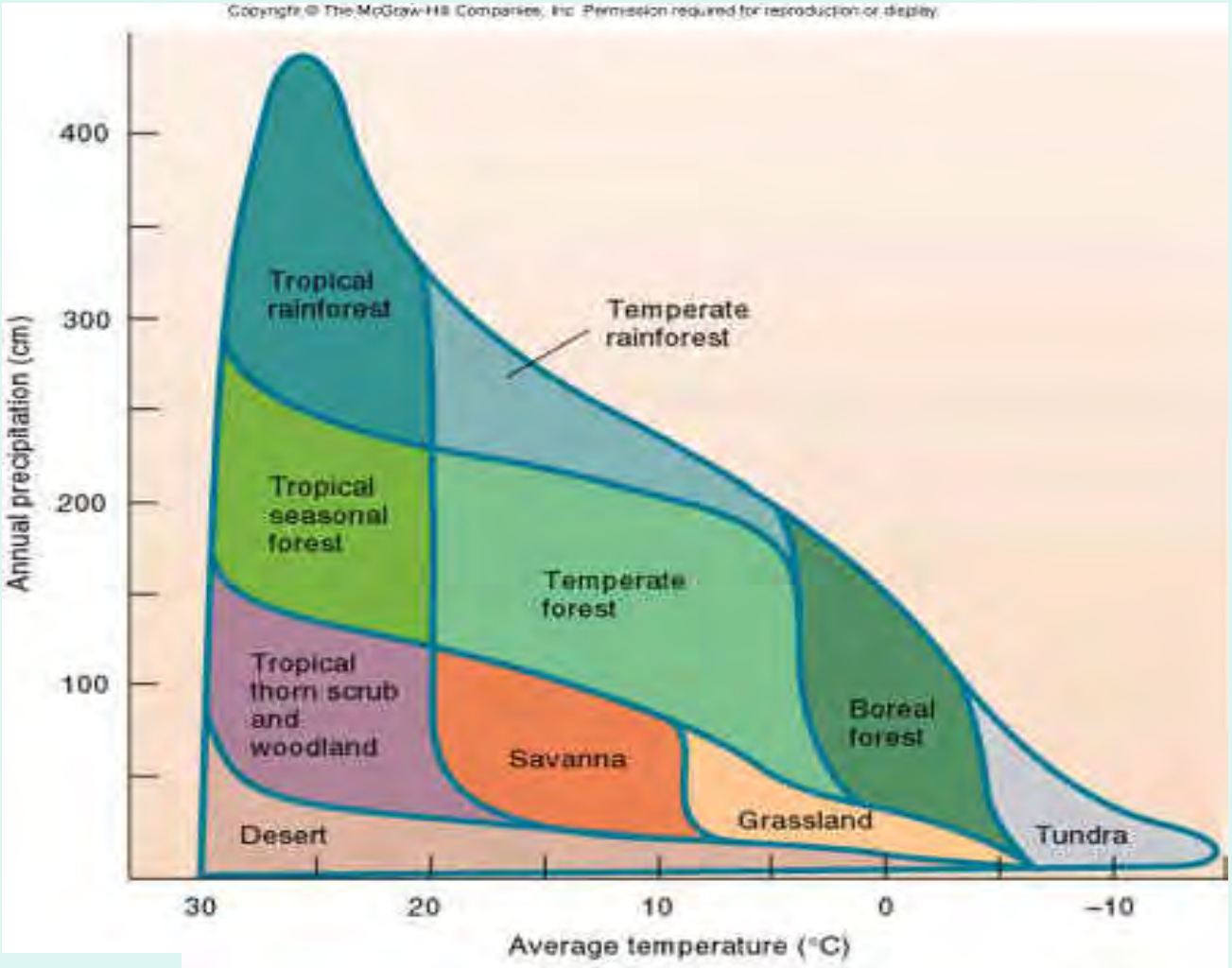
Jurassic (213 – 144Ma) → Cretaceous (144 – 65 Ma)

Major Biomes and Their Vegetation

- **Tundra** – no trees, lichens, grasses and shrubs
- **Taiga (or Boreal Forest)** – coniferous evergreens
- **Temperate forests** – include evergreens (spruce), deciduous forests (oaks), mixed forests, and temperate rain forests (sequoias)
- **Tropical rain forests** – greatest amount of diversity in vegetation (vines, orchids, palms)
- **Grasslands** – grasses, prairie clover
- **Deserts** – cacti, small bushes

Major Terrestrial Biomes

- Geographic **distribution of biomes are dependent on temperature, precipitation, altitude and latitude**
- Weather patterns dictate the type of plants that will dominate an ecosystem



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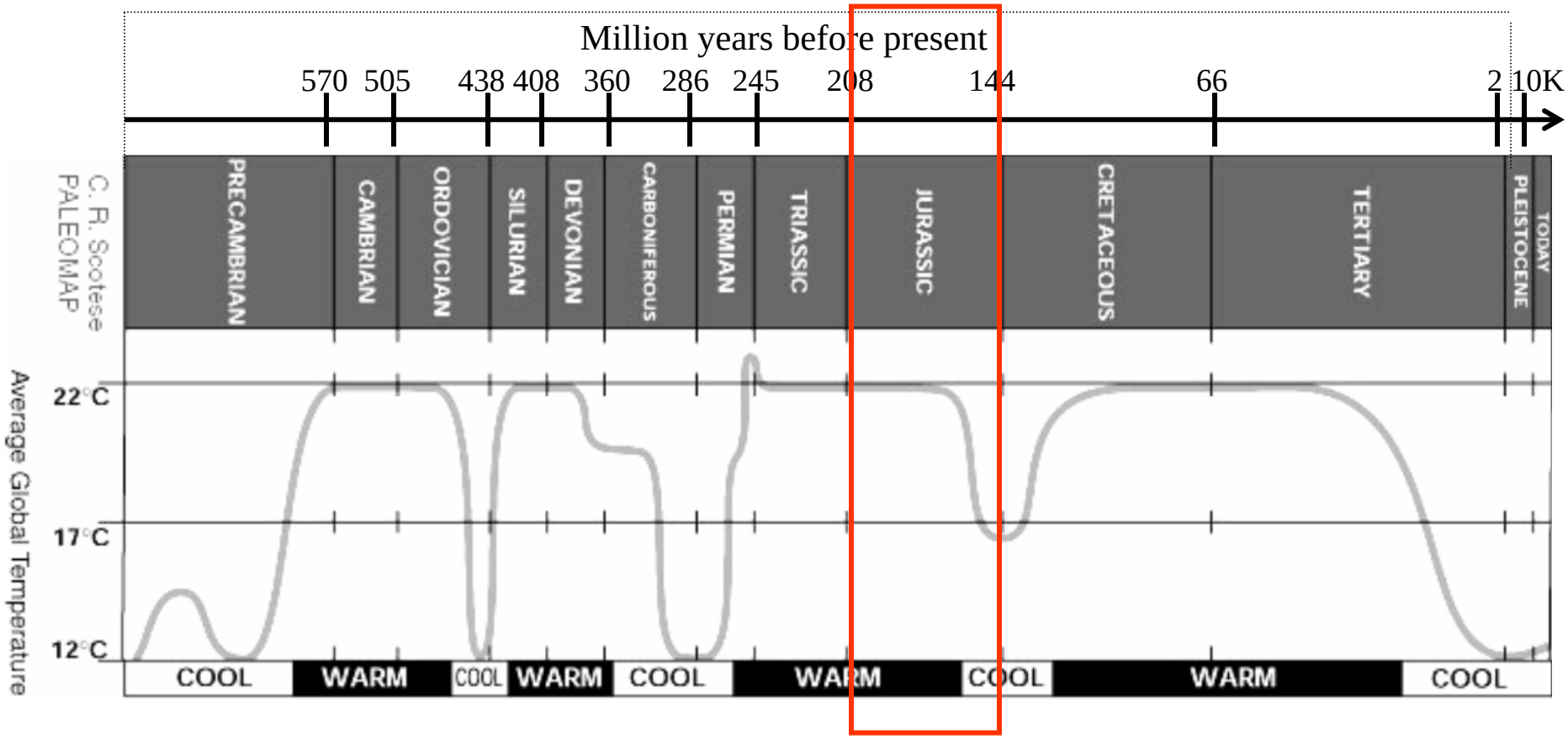
Global Temperature

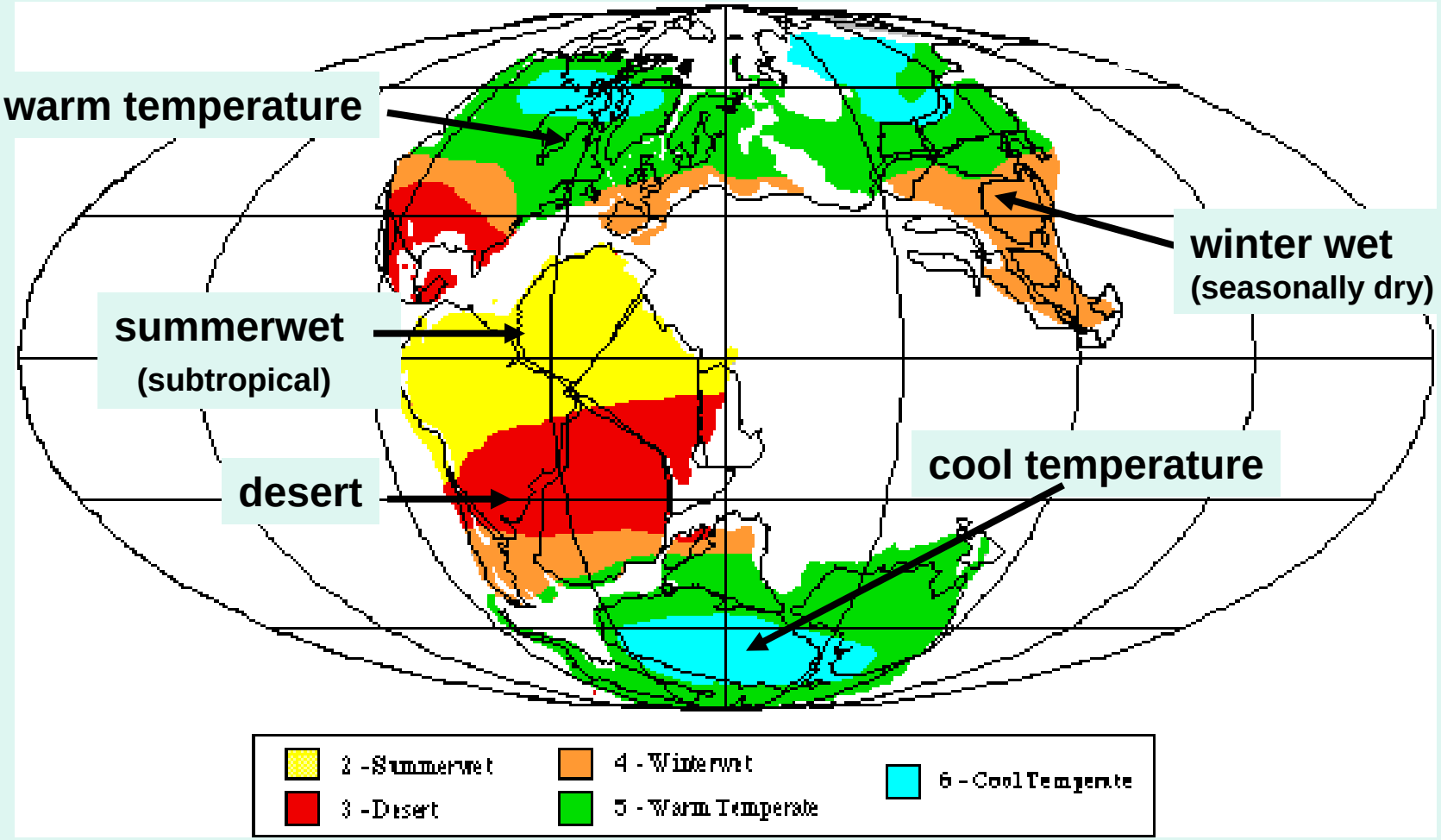


Paleogeographic Biome
Late Jurassic (150 Ma)

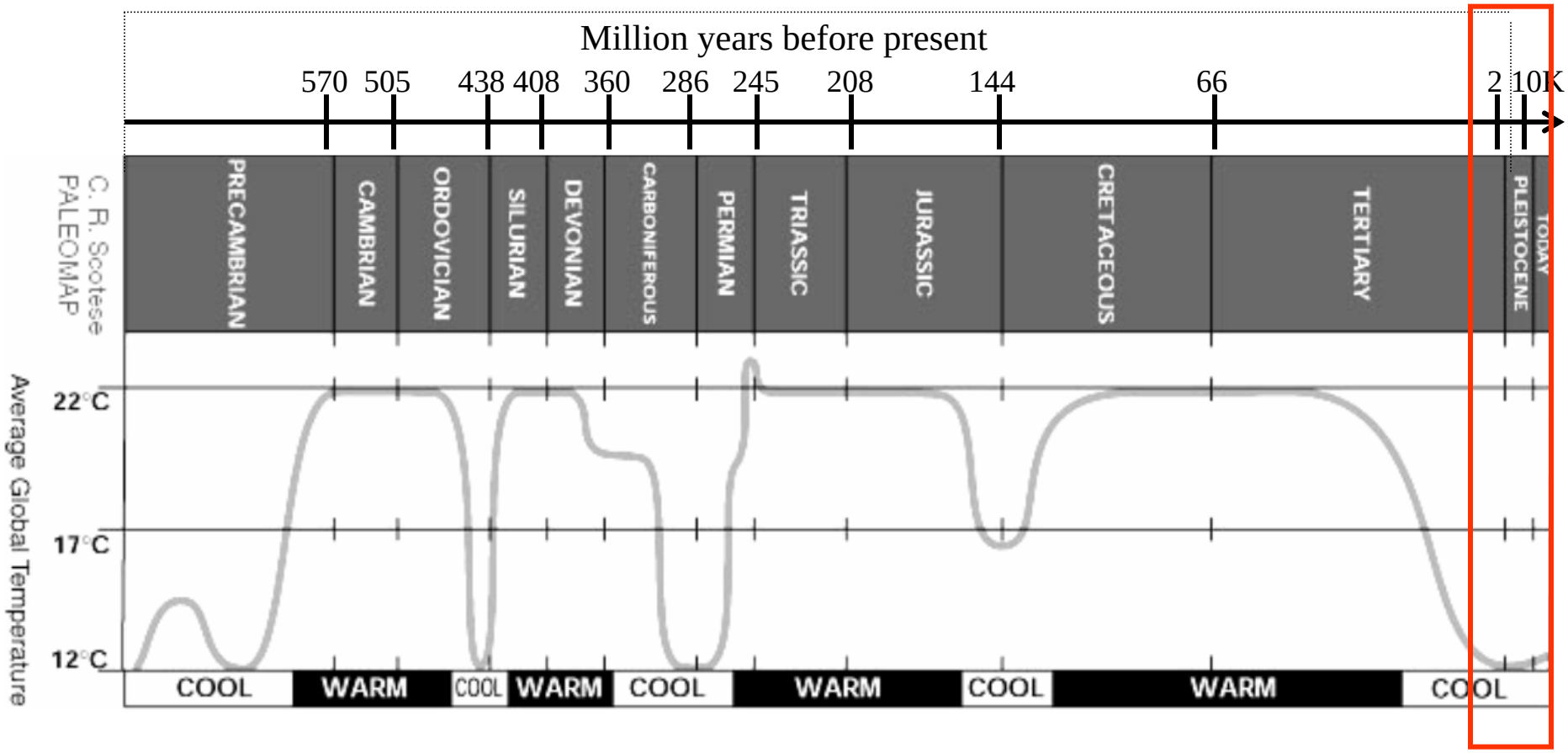
- Fossils of plant life used to reconstruct climate biomes

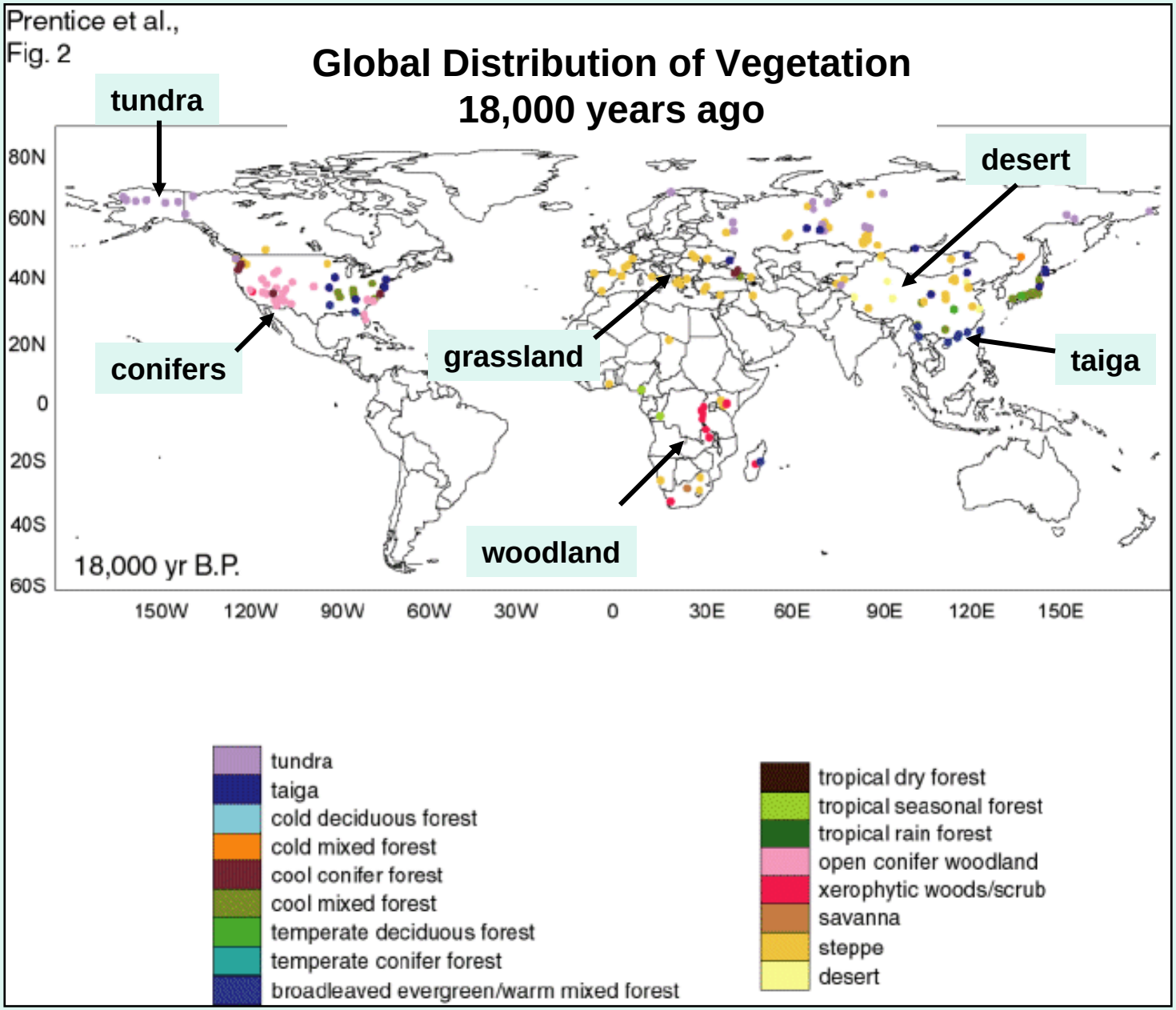
Five Main Biomes:

- **winter wet (seasonally dry)**
- **summer wet (subtropical)**
- **desert**
- **warm temperature**
- **cool temperate**



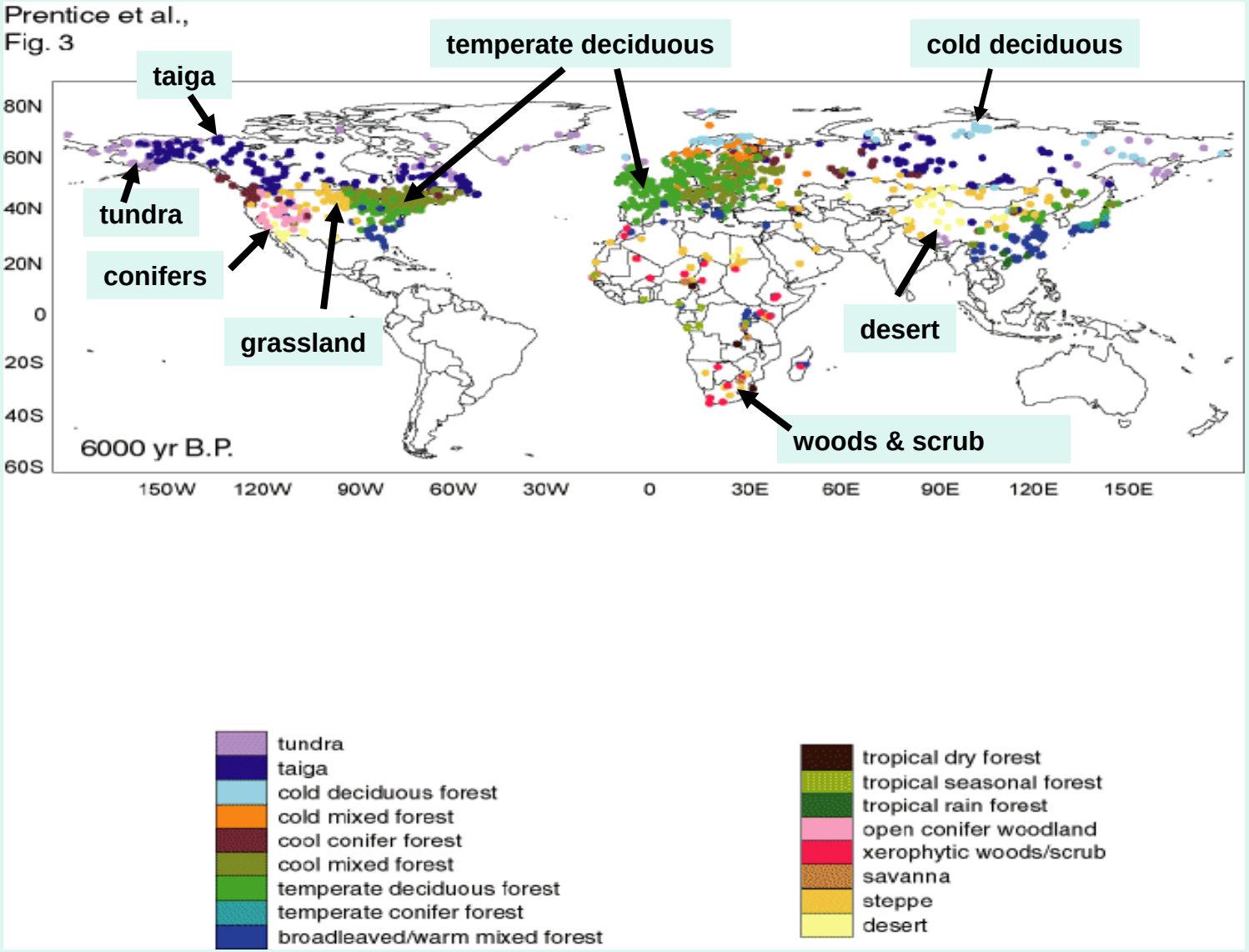
www.geo.arizona.edu/ ~rees/Jurassic.html


Million years before present
570
505
438
408
360
286
245
208
144
66
2
10K
PRECAMBRIAN
CAMBRIAN
ORDOVICIAN
SILURIAN
DEVONIAN
CARBONIFEROUS
PERMIAN
TRIASSIC
JURASSIC
CRETACEOUS
TERTIARY
PLEISTOCENE
TODAY
C. R. Scotese
PALEOMAP
Average Global Temperature
22°C
17°C
12°C
COOL
WARM
COOL
WARM
COOL
WARM
COOL
WARM
COOL



Prentice, C.I., Guiot, J., Huntley, B., Jolly D. and Cheddadi, R., 1996,
Reconstructing biomes from palaeoecological data:
a general method and its application to European pollen data at 0 and 6 ka.
Climate Dynamics 12:185-194.

Global Distribution of Vegetation 6,000 years ago



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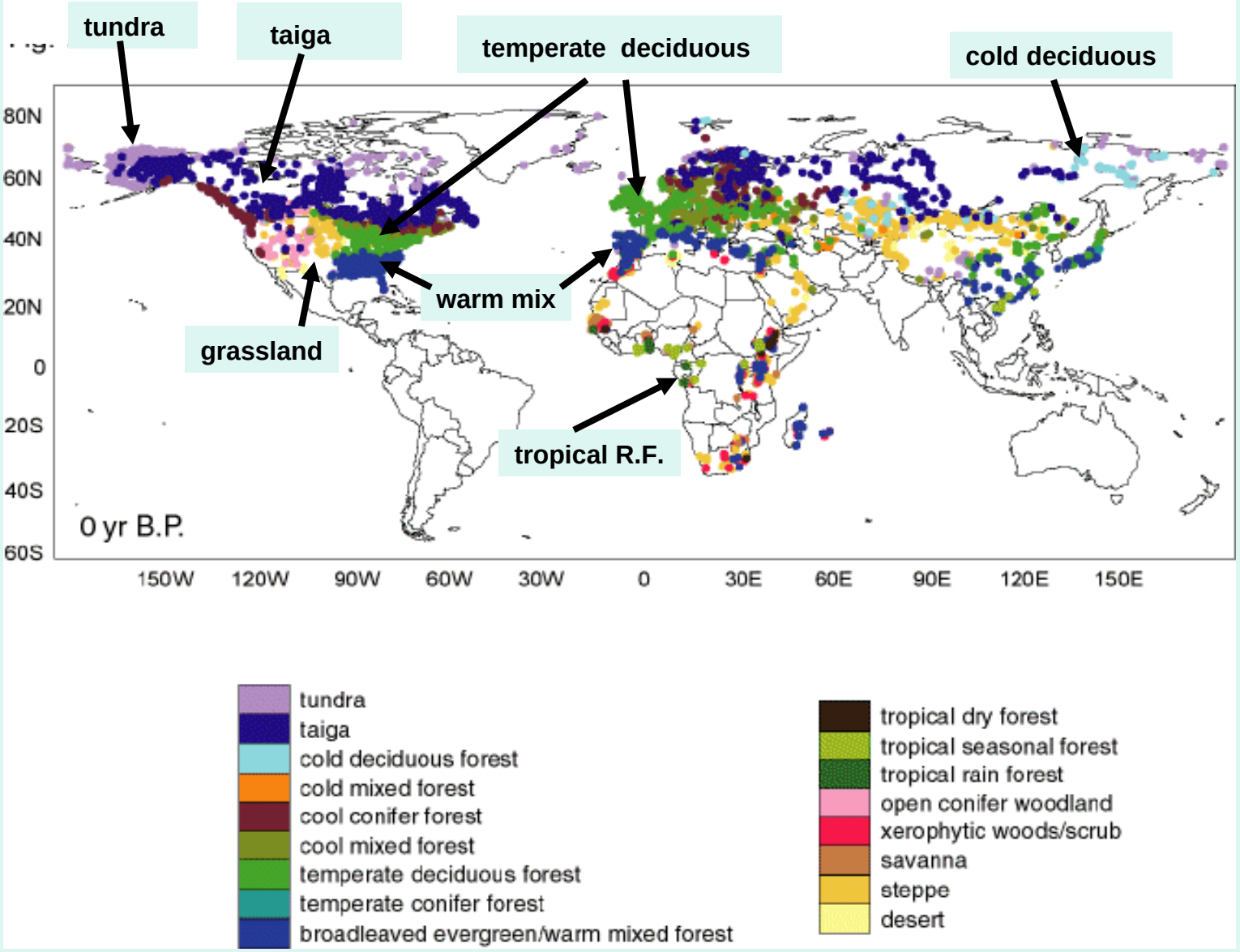
Global Distribution of Vegetation - Present



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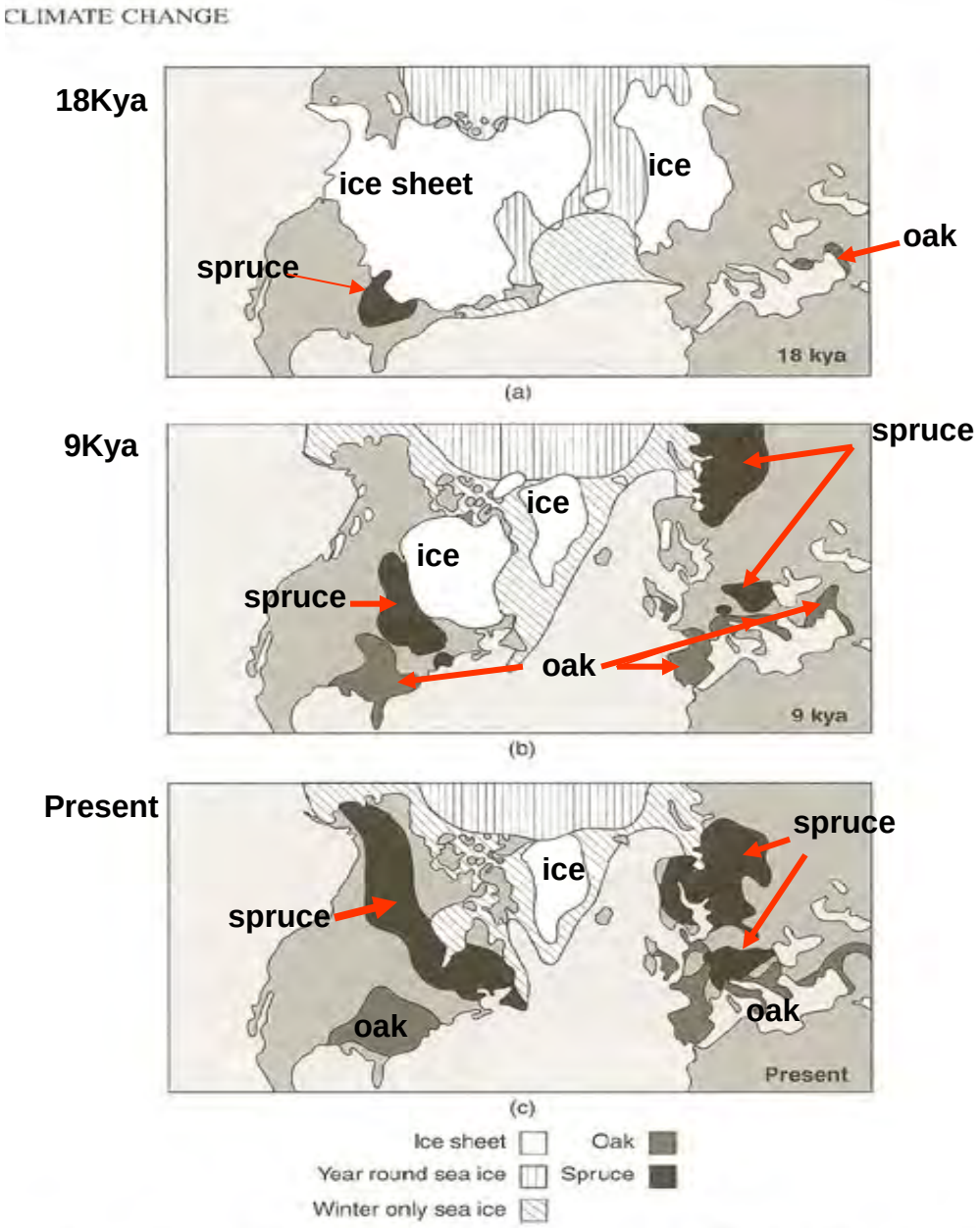
Shifts in Terrestrial Habitat

- 18,000 years ago Spruce trees and oak trees filled small pockets of habitat – as climates warmed Spruce trees migrated into the Northern Hemispheres and the Oak trees expanded in to Southeastern U.S., Western Europe and Southern Europe

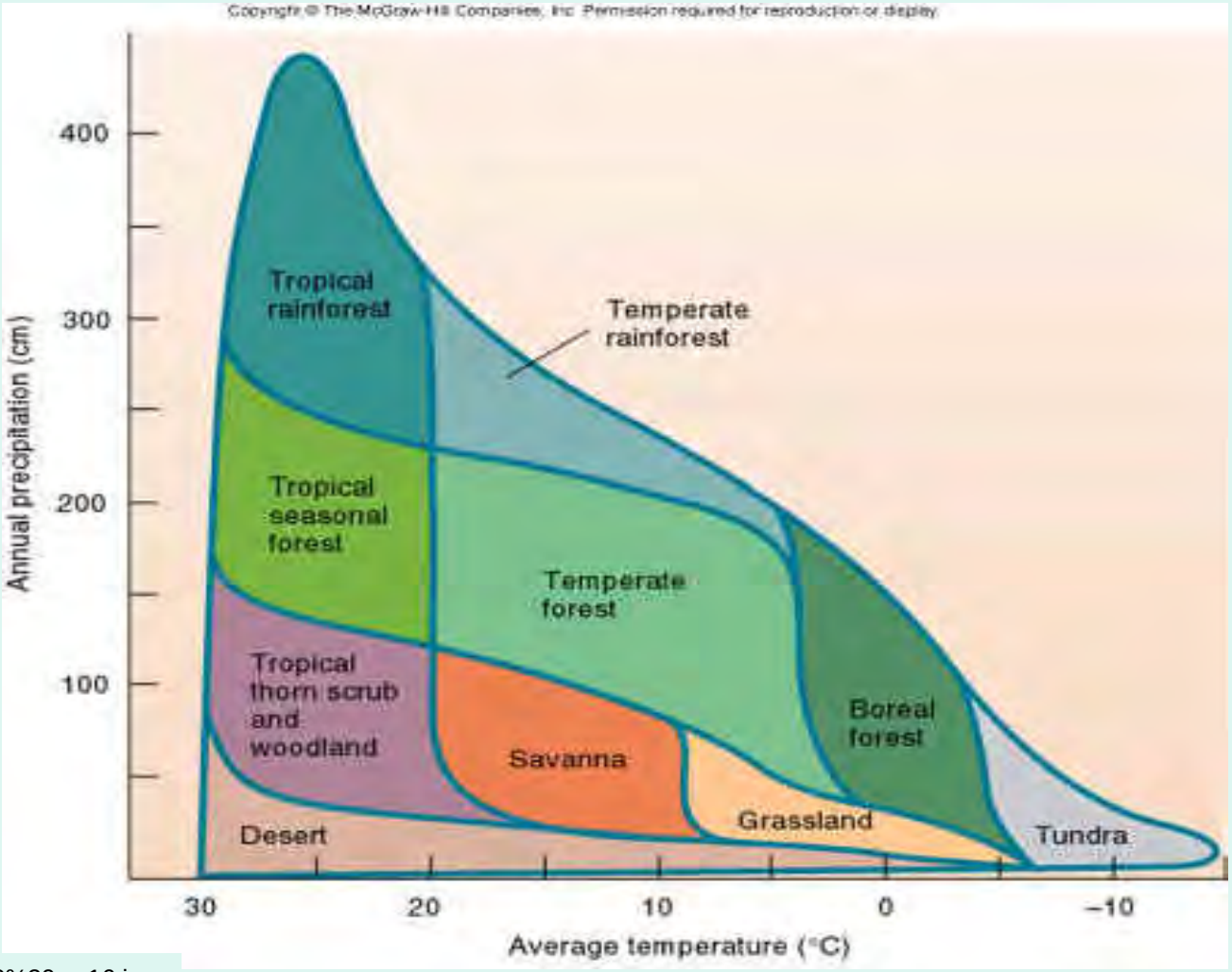
- Shifts in vegetation occur slowly tree species were able to successfully expand into favorable regions



Distribution of spruce and oak forests in Northern Hemisphere since the glacial period 18,000 kya

Major Terrestrial Biomes

- Geographic distribution of biomes are dependent on temperature, precipitation, altitude and latitude
- Weather patterns dictate the type of plants that will dominate an ecosystem



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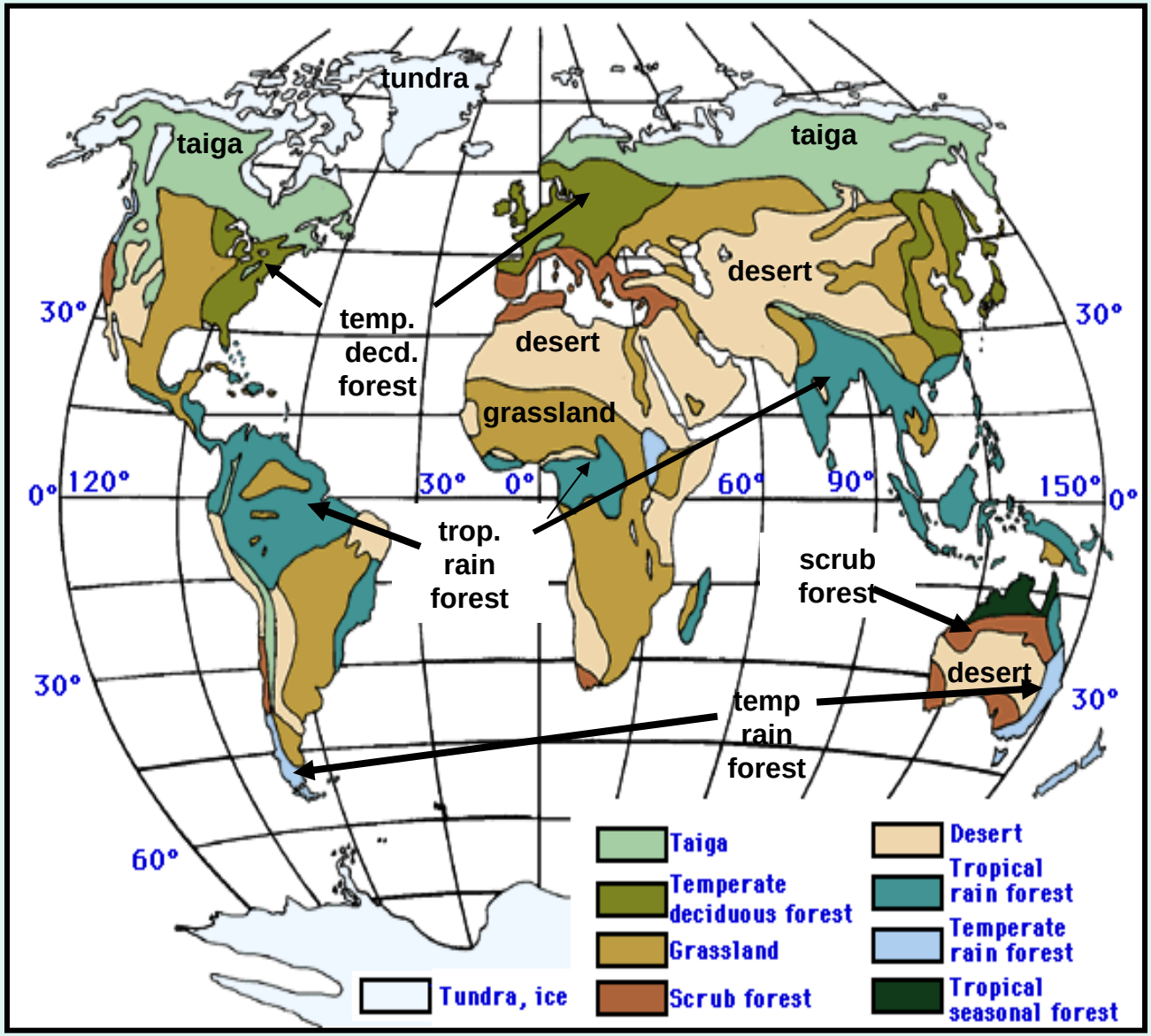
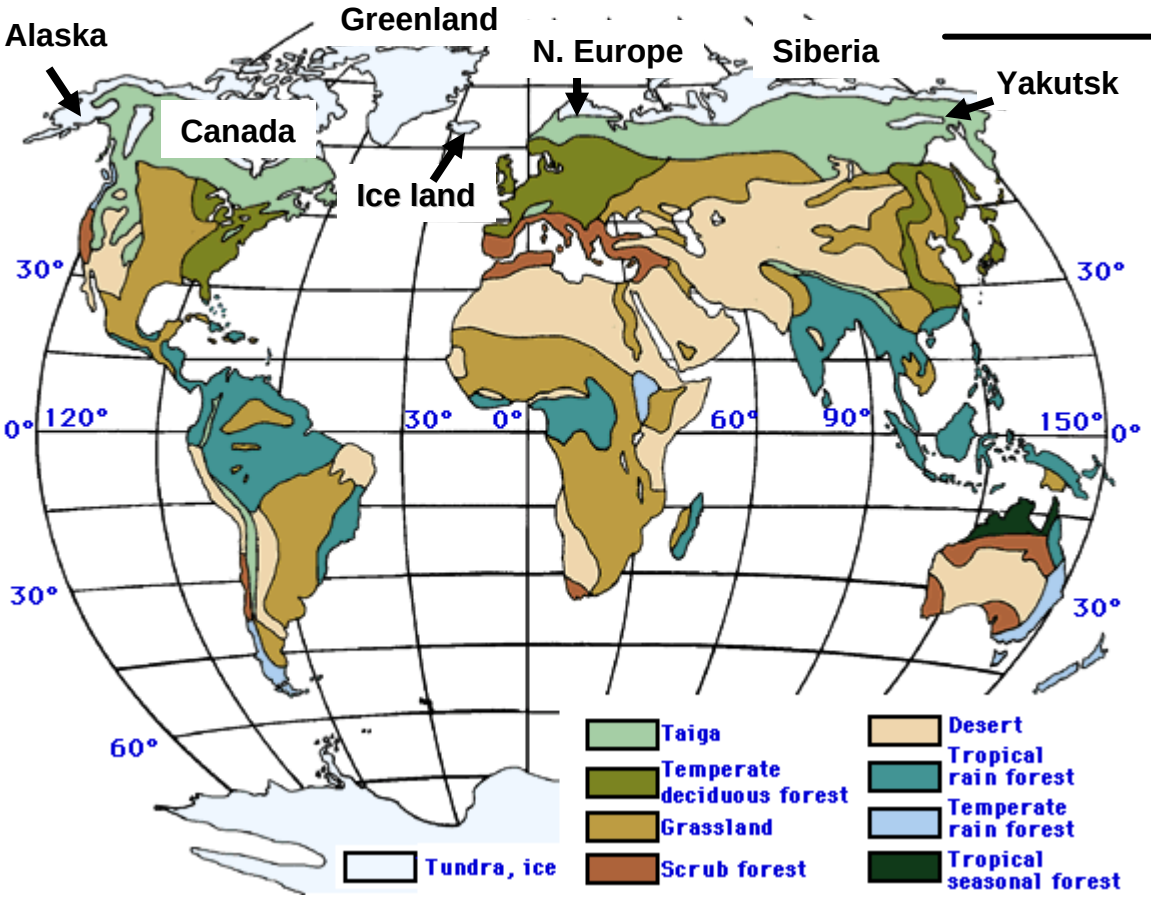
PRESENT DAY BIOMES

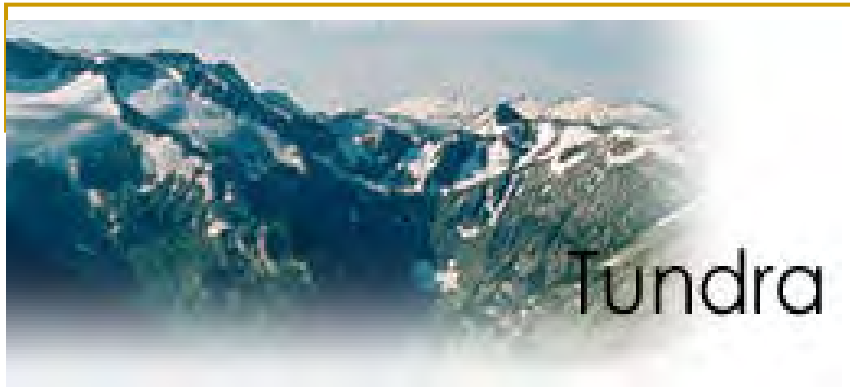


Tundra

Location:
Regions south of the ice caps of the Arctic and extending across North America, Europe and Siberia (high mountain tops)



Average Temperature: -40°C to 18°C
Average Precipitation:
150 to 250 mm of rain per year
Type of vegetation:
Almost no trees due to short growing season and permafrost; lichens, mosses, grasses, and shrubs

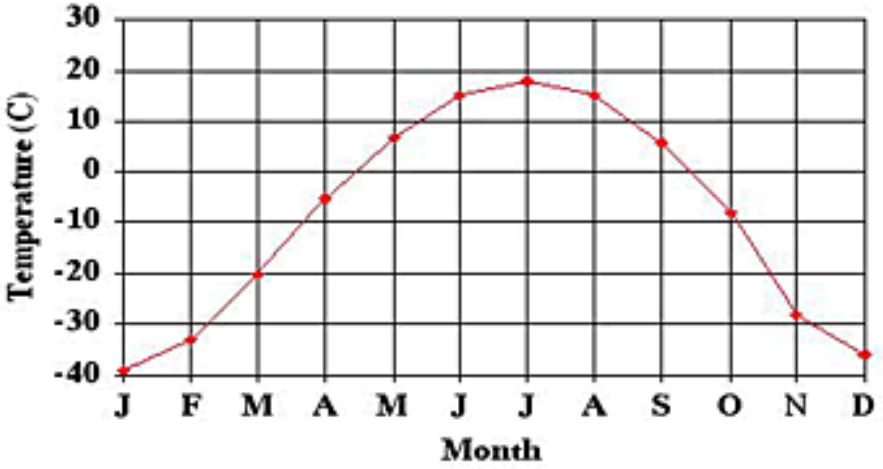


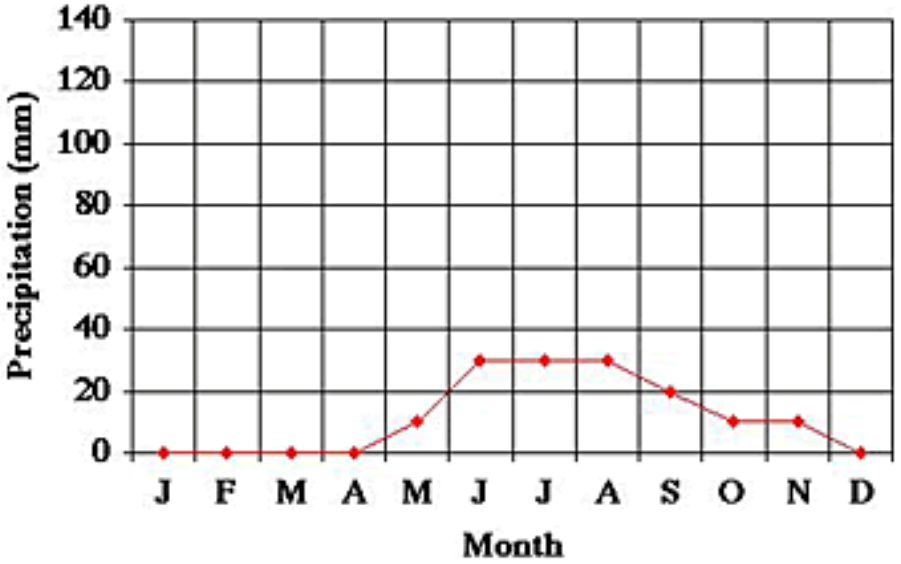
Yakutsk, Russia

Location:

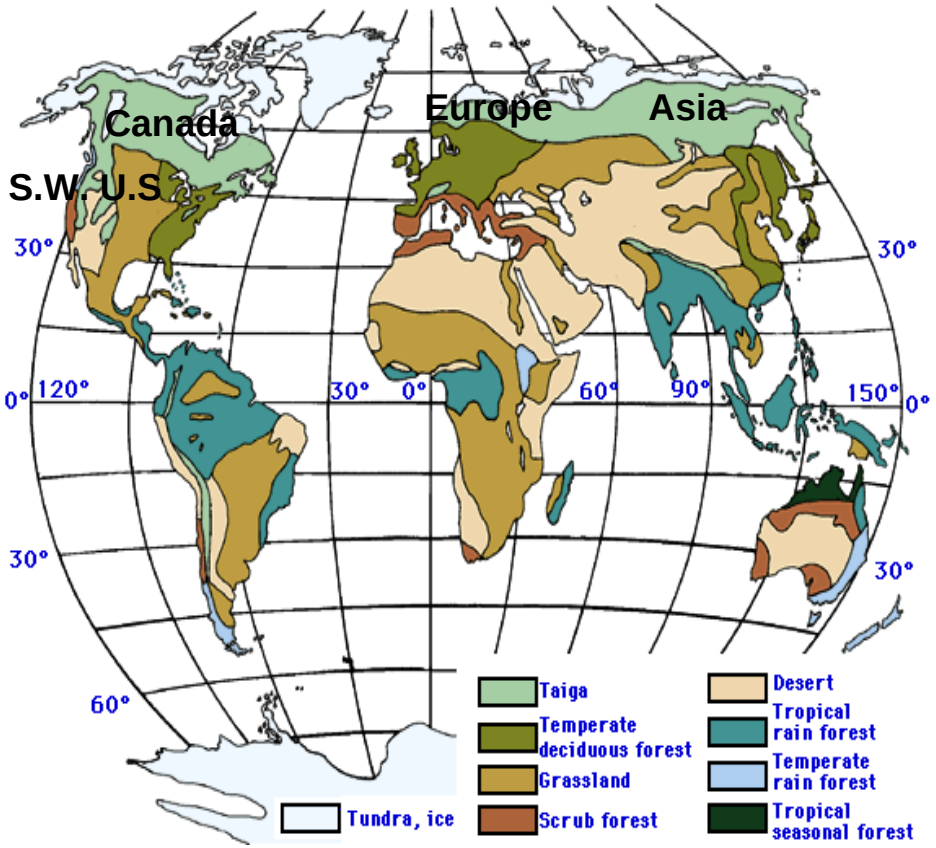
62.1 N; 129 W

Average annual temperature and precipitation





Boreal Forest (Taiga)

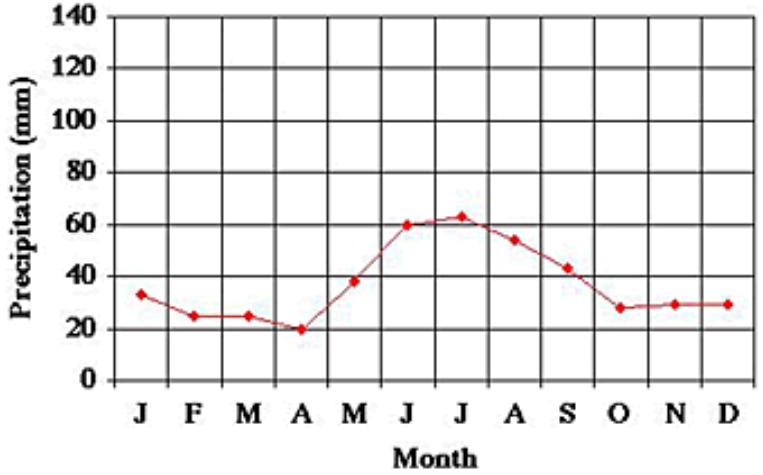


Temperature:
-40°C to 20°C, average summer temperature is 10°C
Precipitation:
300 to 900 millimeters of rain per year
Vegetation:
Coniferous-evergreen trees
Location:
Canada, Europe, Asia, and the United States
Other:
Coniferous forest regions have cold, long, snowy winters, and warm, humid summers; well-defined seasons, at least four to six frost-free months

Average annual temperature and precipitation

Beaverlodge, Alberta, Canada

55ºN; 119º W



Temperate Forests

Four types:
1. deciduous forests
2. evergreen forests
3. mixed deciduous and evergreen
4. temperate rain forests

Location:
Eastern United States, Canada, Europe, China, and Japan

<u>Average Yearly Temperature</u>:
Between -30°C to 30°C; hot summers, cold winters; sunlight varies between seasons

<u>Average Yearly Precipitation</u>:
750 to 1,500 mm of rain per year

<u>Vegetation</u>:
Deciduous - Broadleaf trees (oaks, maples, beeches), shrubs, perennial herbs, and mosses.

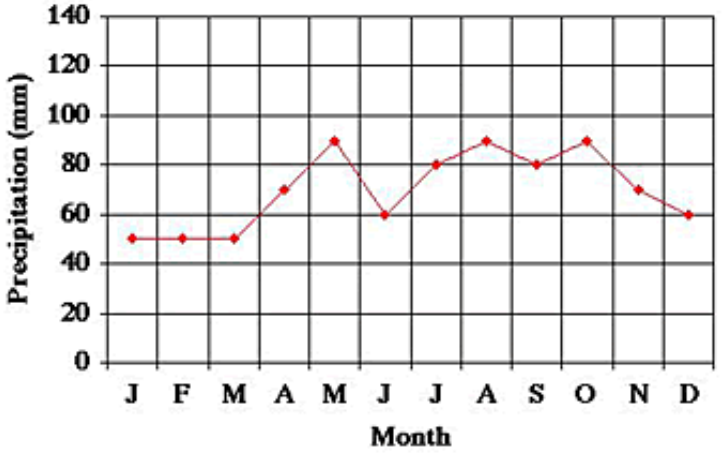
Evergreen – (N. America) – Spruce, Hemlock, Pine and Fir trees
Temperate Rainforests – (CA, OR, & WA) – made up of Red wood and Sequoias

www.windows.ucar.edu/.../ earth/forest_eco.html

Temperate Deciduous Forest

Staunton, Virginia, United States
38ºN; 79ºW

Average annual temperature and rainfall



Tropical Forests

General Characteristics:

Average Temperature: 20°C to 25°C, must remain warm and frost-free

Average Precipitation: 2,000 to 10,000 millimeters of rain per year

Average Humidity: Between 77 – 88%

Types of Vegetation: Large trees reaching up to 240 feet, have the most diverse trees than any other biome: vines, orchids, ferns

Tropical rainforests:

- Cover less than 6% of Earth's land surface
- Produce more than 40% of Earth's oxygen
- Contain more than half of all the worlds plants and animals
- ¼ of all medicines come from rainforest plants
- Scientists believe more than 1400 tropical plants thought to be potential cures to cancer

Tropical Rainforest

<u>3 major geographical areas</u>:

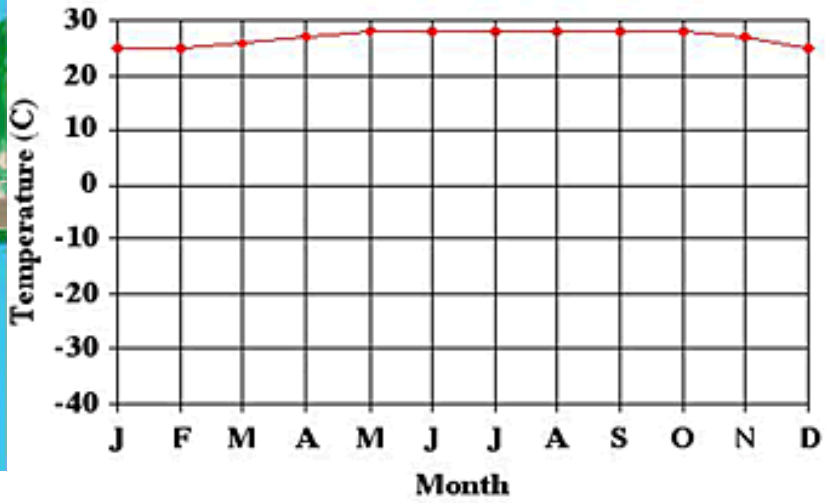
1. **America**: Amazon river basin
2. **Africa**: Zaire basin, small area of W. Africa, Eastern portion of Madagascar
3. **Asia**: West coast of India, Assam, S.E. Asia, New Guinea and Queensland, Australia

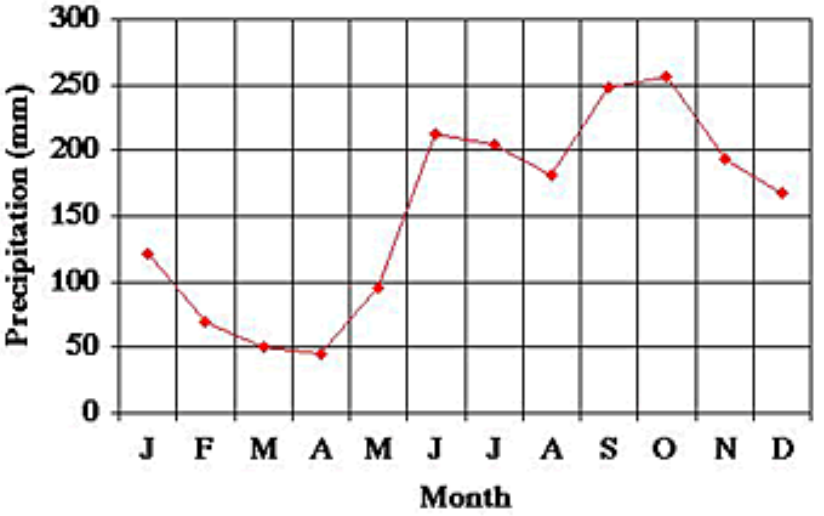
"Rainforests", http://passporttoknowledge.com/rainforest/GEOsystem/Maps/se_asia.html, (3/18/02)

Campa Pita, Belize

15 N latitude

Average annual temperature and precipitation





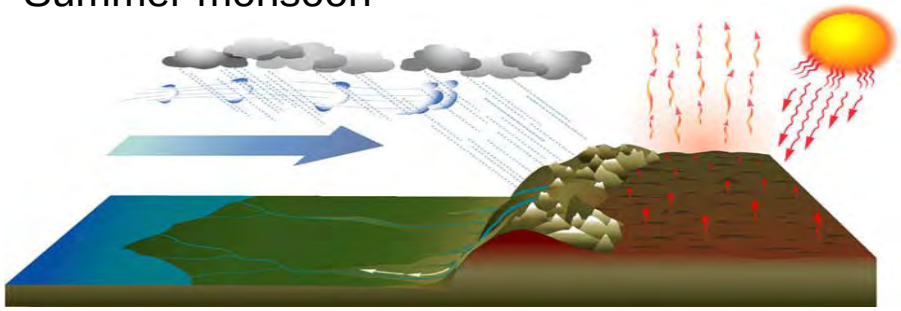
Southeast Asia Tropical Rainforest Monsoons role

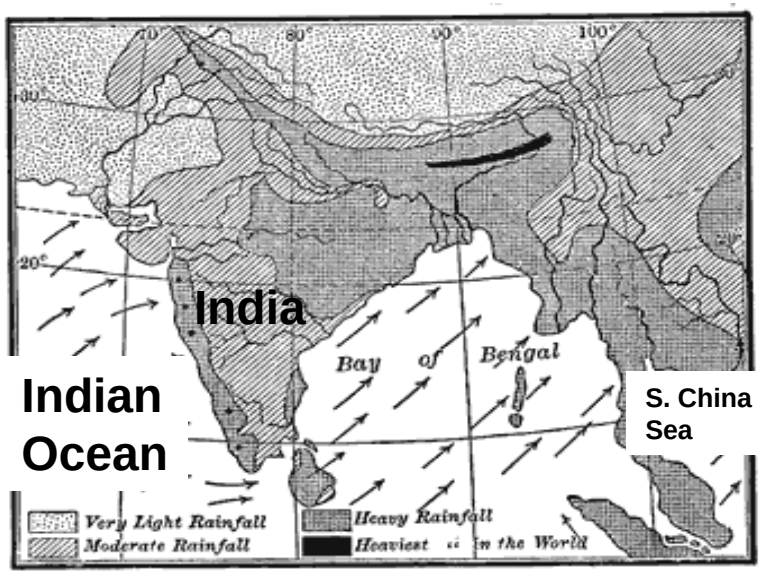
- SE Asia has a tropical wet climate which is influenced by ocean wind systems originating in the Indian Ocean and China Sea
- 2 monsoon seasons:
  - Northeast monsoons (Oct. – Feb) – bring heavy rains to Eastern side of the islands
  - Southwest monsoons (April – Aug) – more powerful of the two seasons – brings heavy rainfall to the western side of the islands – Eastern side of islands dry – but windy (due to rain shadow)

- Change in monsoon cycle bring heavy consequences
  - Ex. 1992 – 1993 – logging degraded primary foresting making it vulnerable to fires. A drought brought on by El Nino created devastating fires destroying 27,000 km^2 of acreage.
  - In 1998 the same type of thing happened again when El Nino created a weak monsoon season – destroying many plant and animal species.

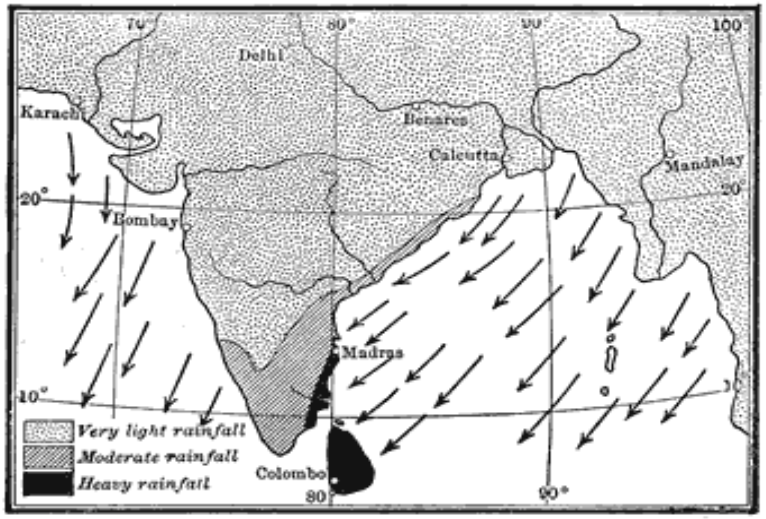
Monsoons Seasons

Summer monsoon





SUMMER MONSOON WINDS



WINTER MONSOON WINDS

Grasslands

Location: The prairies of the Great Plains of North America, the pampas of South America, the veldt of South Africa, the steppes of Central Eurasia, and surrounding the deserts in Australia

Temperature: Dependent on latitude, yearly range can be between -20°C to 30°C

Precipitation: About 500 to 900 mm of rain per year

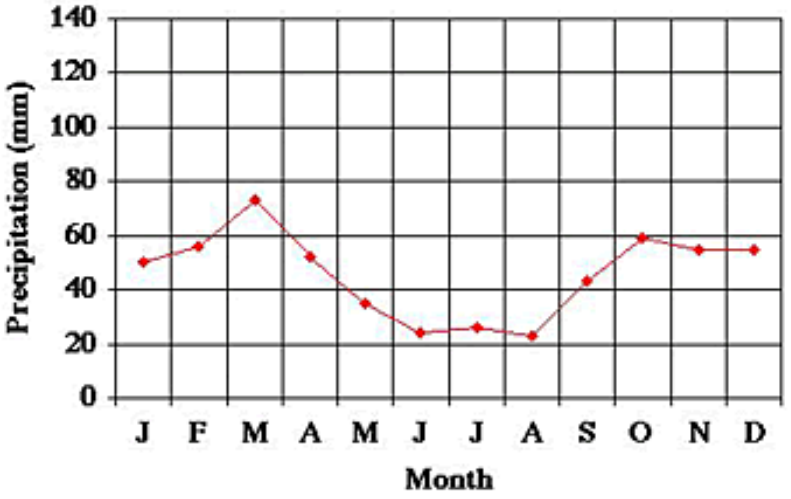
Vegetation: Grasses (prairie clover, salvia, oats, wheat, barley, coneflowers)

Other: Found on every continent except Antarctica

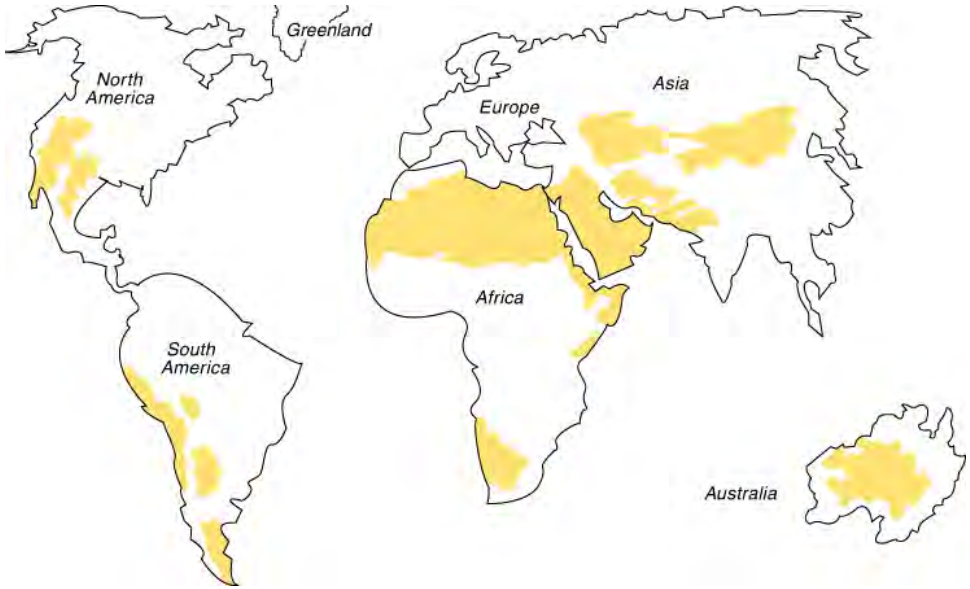
Average annual temperature and rainfall

Ingeniera White, Argentina

40ºS; 6ºW



Deserts



Location: Found north and south of the Equator

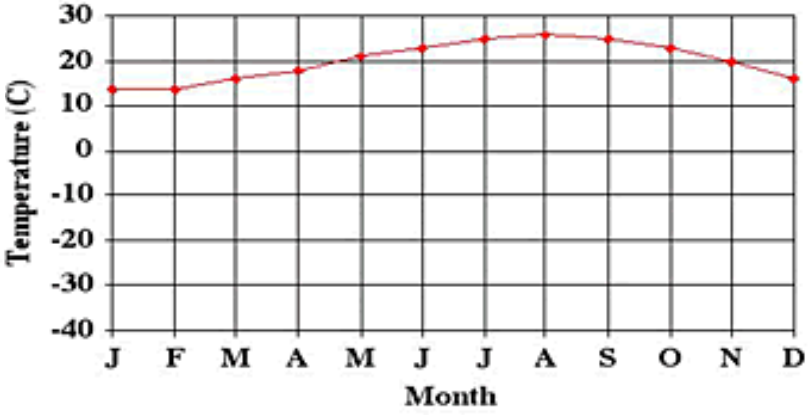
Temperature: Average of 38°C (day), average of -3.9°C (night)

Precipitation: About 250 mm of rain per yr

Vegetation: Cacti, small bushes, short grasses

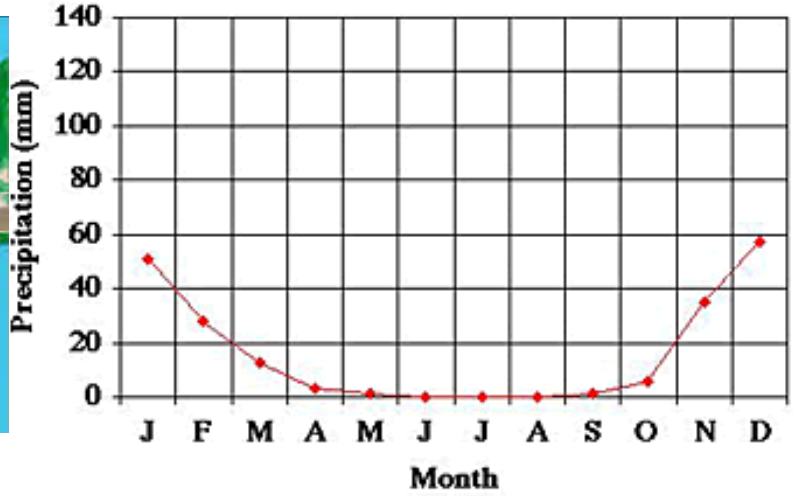
Other:
Perennials survive for several years by becoming dormant and flourishing when water is available. Annuals are referred to as ephemerals because some can complete an entire life cycle in weeks.

Average yearly temperature and rainfall



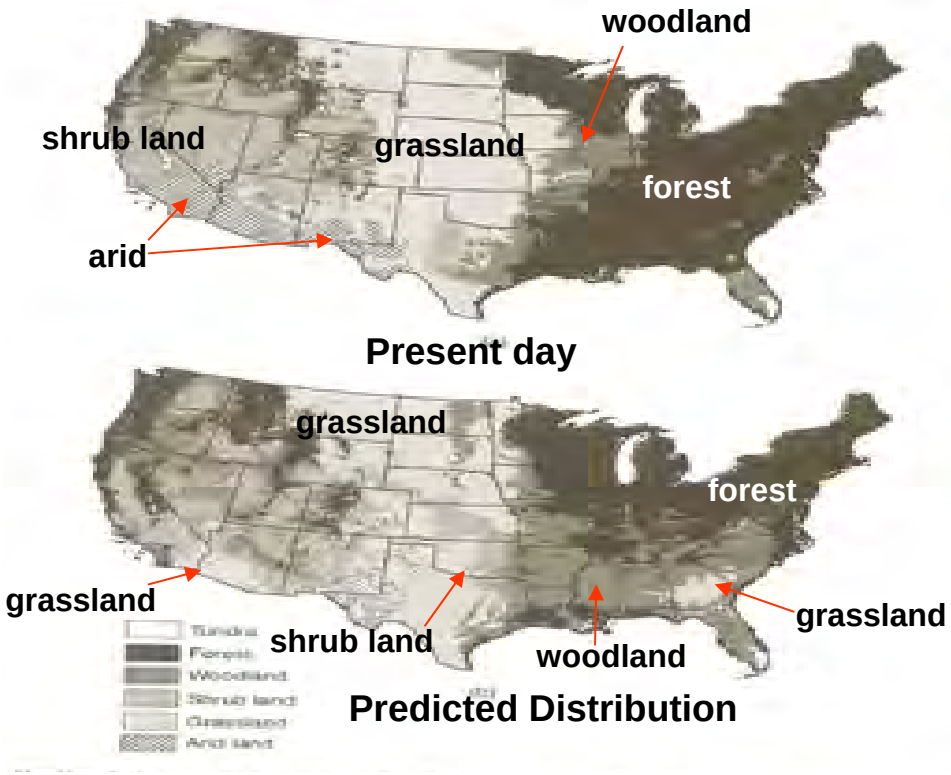
El-Oasr el-Akhdar, Egypt

26ºS; 30ºE



So … what are the predictions?????

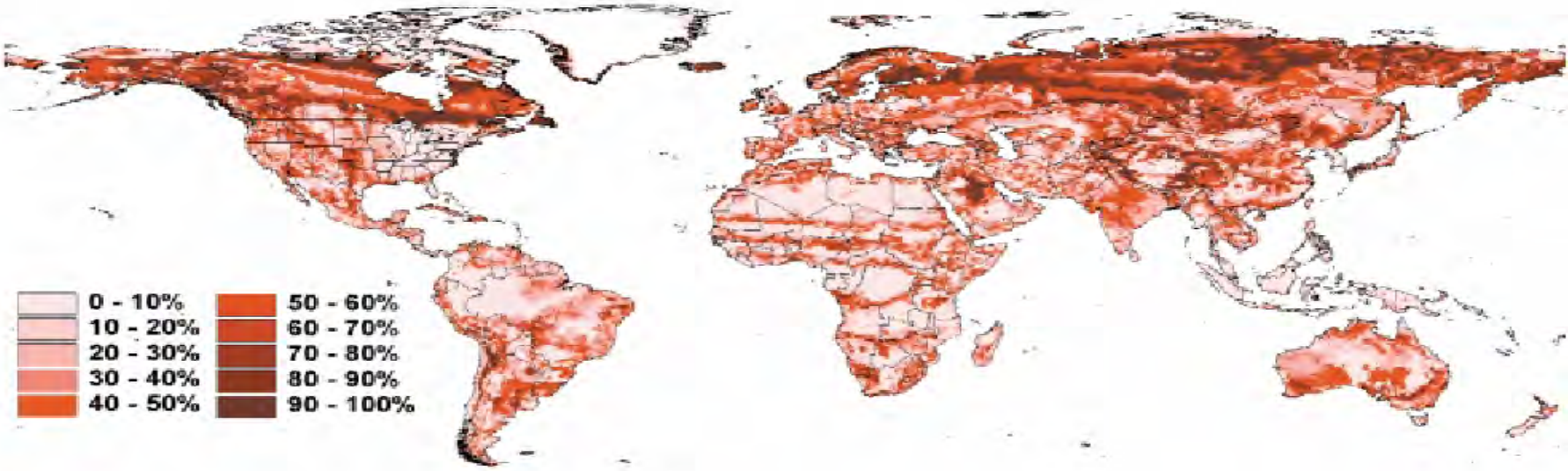
- Arid deserts in Southwestern U.S. will shrink as precipitation increases
- Savanna/shrub/woodland systems will replace grasslands in the Great Plains
- Eastern U.S. – forests will expand northerly – weather conditions will become more severe
- Southeastern U.S. – increasing droughts will bring more fires – triggering a rapid change from broadleaf forests to Savannas



Predicted Change in Biomes

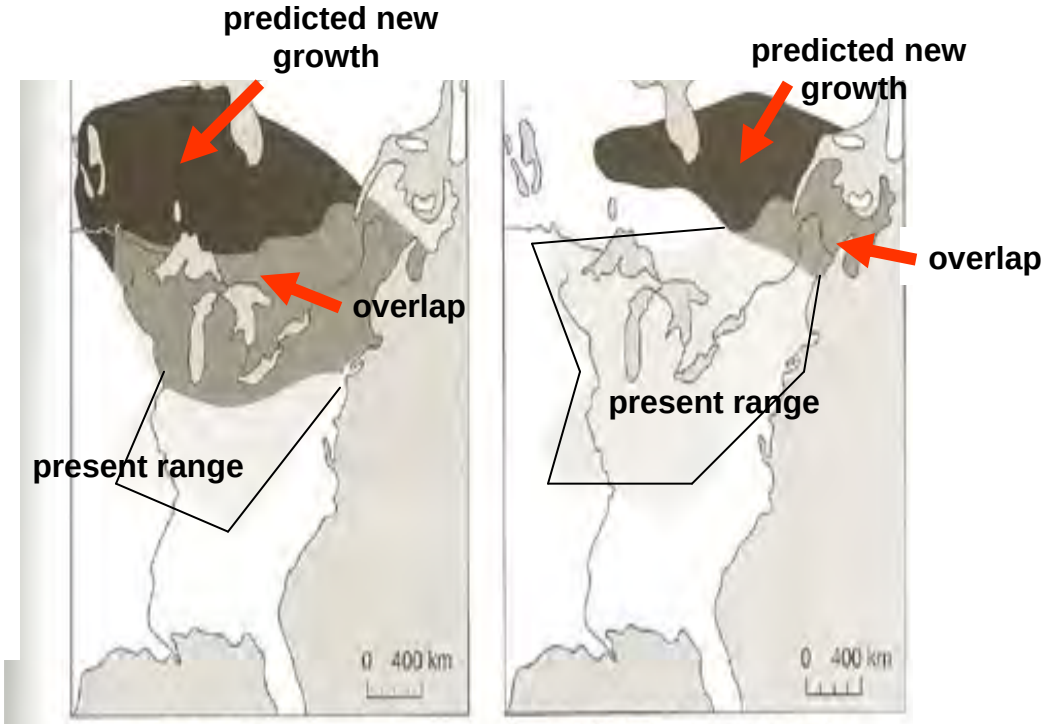
Loss of existing habitat that could occur under doubling of CO_2 concentration. Shades of red indicate percentage of vegetation models that predicted a change in biome type.

rming and Terrestrial Biodiversity Dedline



Predictions of Sugar Maple in Eastern North America

Distribution of Sugar Maple in Eastern North America will change due to an increase in temperature and a decrease in moisture shifting further north east.



Prediction based on increased temperature

Prediction based on increased temperature and decrease precipitation

More Predictions

- Douglas Fir found in wet coastal mountains of CA and OR will shrink in low lands and be replaced by Western pine species which are more drought tolerant.

- Overall Western U.S. climate is predicted to shift to favor more drought tolerant species of pine

Western Hemlock and Douglas fir found on Western slope

Wet western slope will shrink and be replaced by pine and oak

Eastern slope will become drier and shift to Juniper and Sagebrush

Frequency of forest fires will increase, reducing total American boreal forest area.

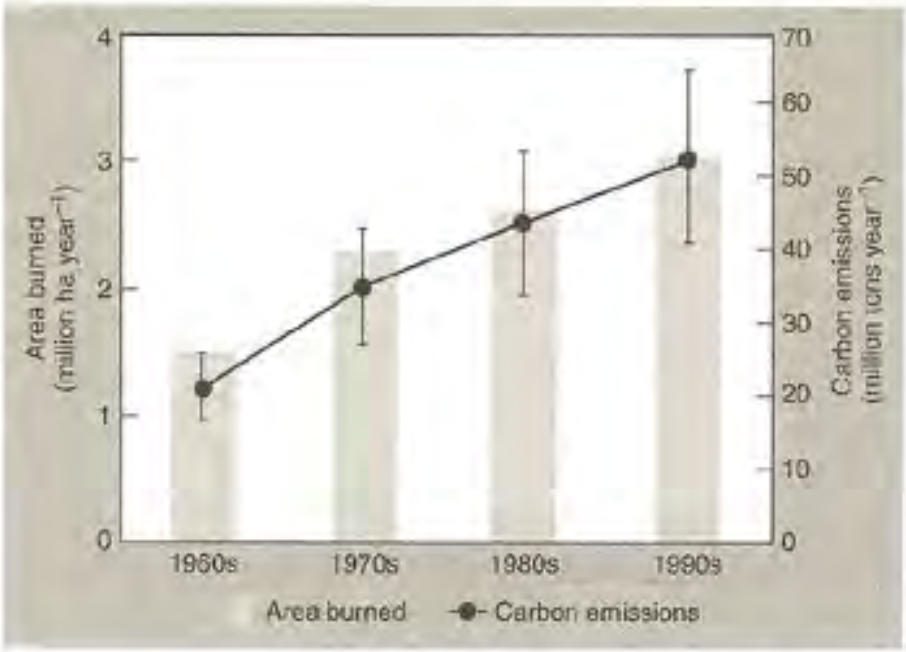


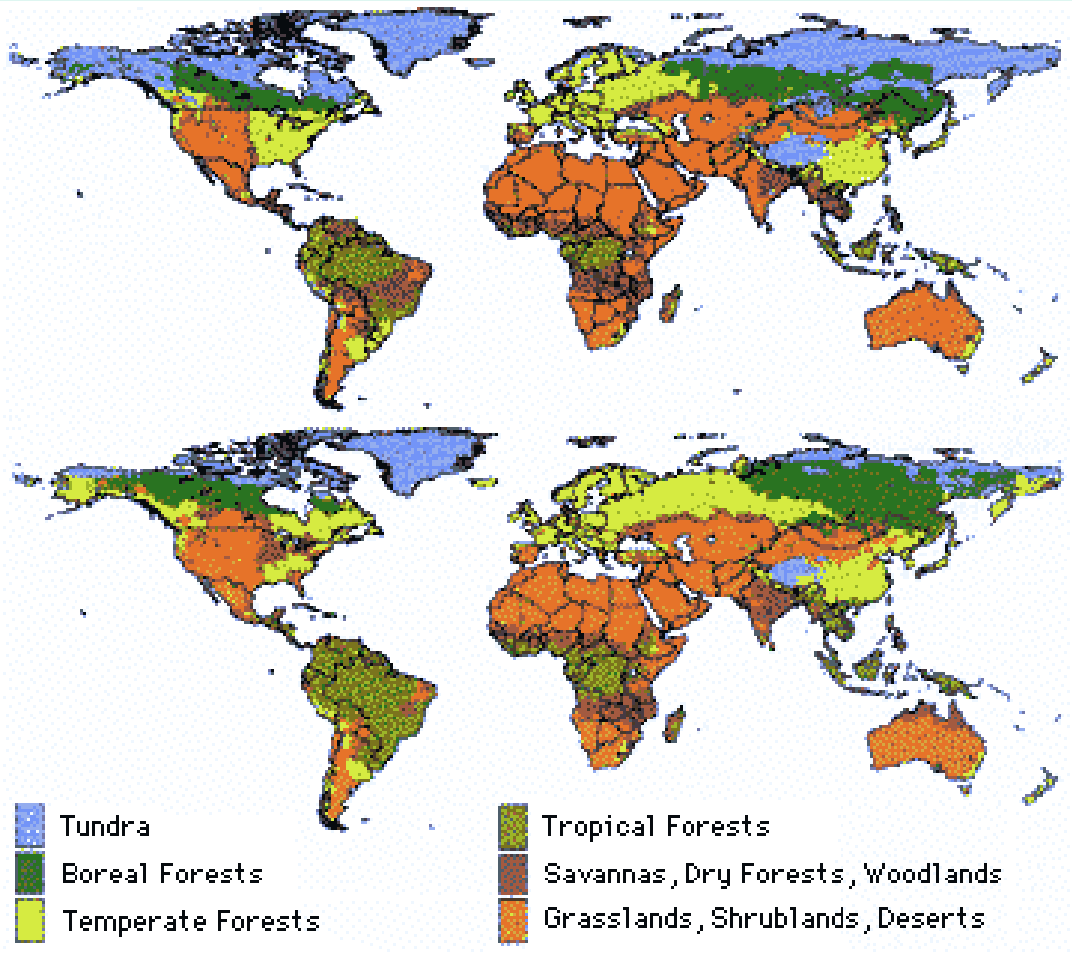
Fig. 6.8 In North American boreal forests, the average forest area that burned in 10-year periods doubled over 30 years. Carbon emissions into the atmosphere increased from 21 to 53 million tons per year (Senkowsky S 2001. A burning interest in boreal forests: researchers in Alaska link fires with climate change. *Bioscience* **51**(11): 916–921. Copyright, American Institute of Biological Sciences).

Shifts in Terrestrial Habitat

- It is predicted that at the end of this century there will be large scale shifts in the global distribution of vegetation in response to anthropogenic climate change.

- With man doubling the amount of carbon dioxide entering into the atmosphere the climate is changing more rapidly then plant migration can keep up.

Potential distribution of the major world biomes under current climate conditions



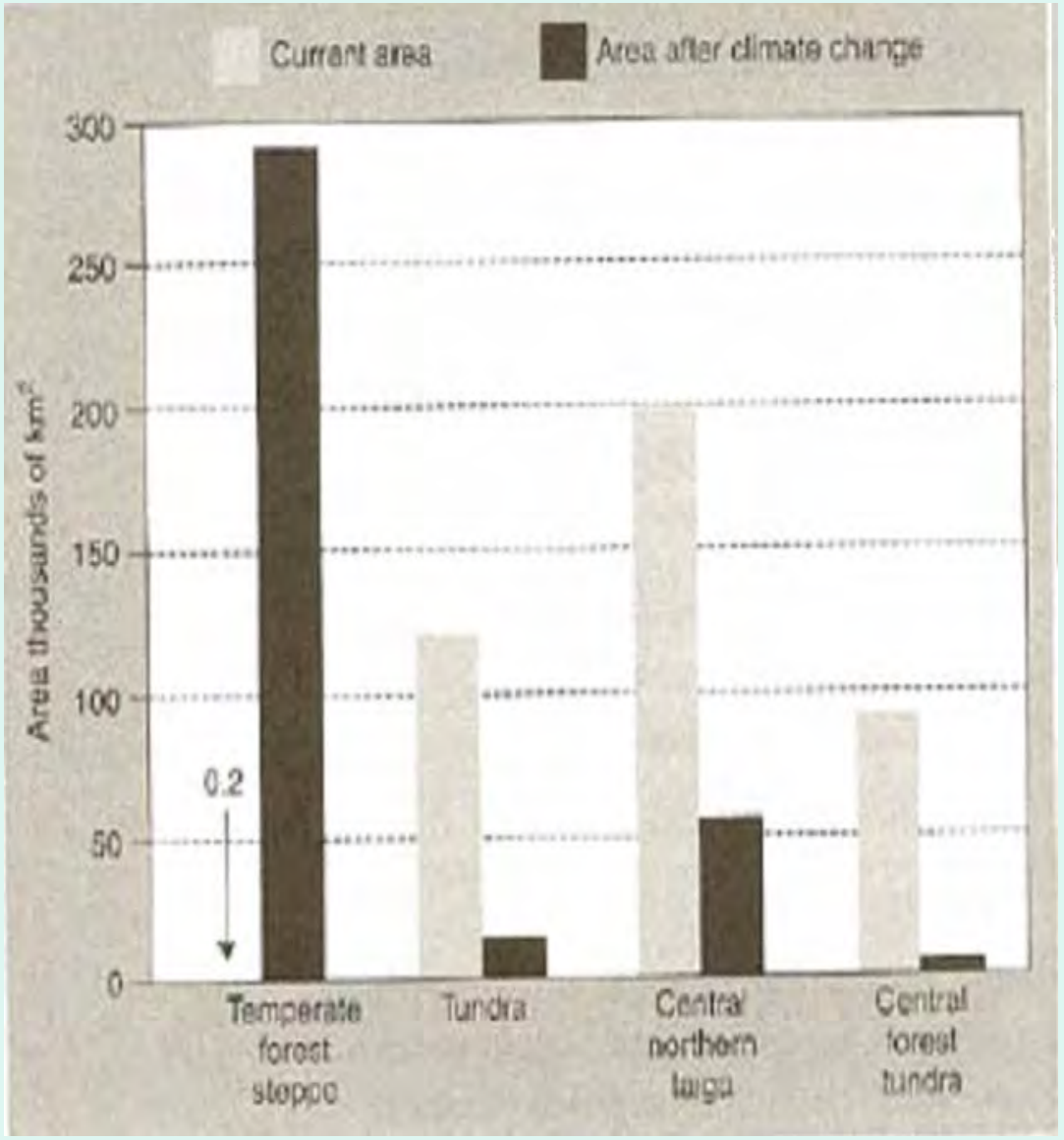
Projected distribution of the major world biomes by simulating the effects of 2xCO2-equivalent concentrations

www.usgcrp.gov/usgcrp/ seminars/960610SM.html

Boreal and Alpine Vegetation

- Research indicates the greatest amount of change will occur at the higher latitudes
- Northern Canada and Alaska are already experiencing rapid warming and reduction of ice cover
- Vegetation existing in these areas will be replaced with temperate forest species
- Tundra, Taiga and Temperate forests will migrate pole ward
- Some plants will face extinction because habitat will become too small (ex. Mountain tops of European Alps)

Predicted changes in Siberian vegetation in response to doubling of CO_2



Grasslands and Shrub Lands

- Grassland will change to deserts or shrub lands
  - Exposing greater amounts of soil
  - Increasing soil temperature – poor nitrogen content – poor plant growth
  - Barren soil exposed to winds and transported into atmosphere as dust and trapping IR – leading to more warming
- Models of:
  - Climate change
  - Plant growth
  - Soil – water

Predict shifts in distribution of major North American prairie grasses over a 40 year period

Those at Risk

- Northern countries (Russia, Sweden, Finland) ½ of existing terrestrial habitats at risk
- In Mexico, it's predicted that 2.4% of species will lose 90% of their range and threatened with extinction by the year 2055
- Population at greatest risk are the rare and isolated species with fragmented habitats or those surrounded by water, agriculture or human development
- Polar bears facing extinction by prolonged ice melts in feeding areas along with decline in seal population

- 35% of worlds existing terrestrial habitat predicted to be altered

- Studies found that deforestation in different areas of the globe affects rainfall patterns over a considerable region

  - Deforestation in the Amazon region of South America (Amazonian) influences rainfall from Mexico to Texas and in the Gulf of Mexico

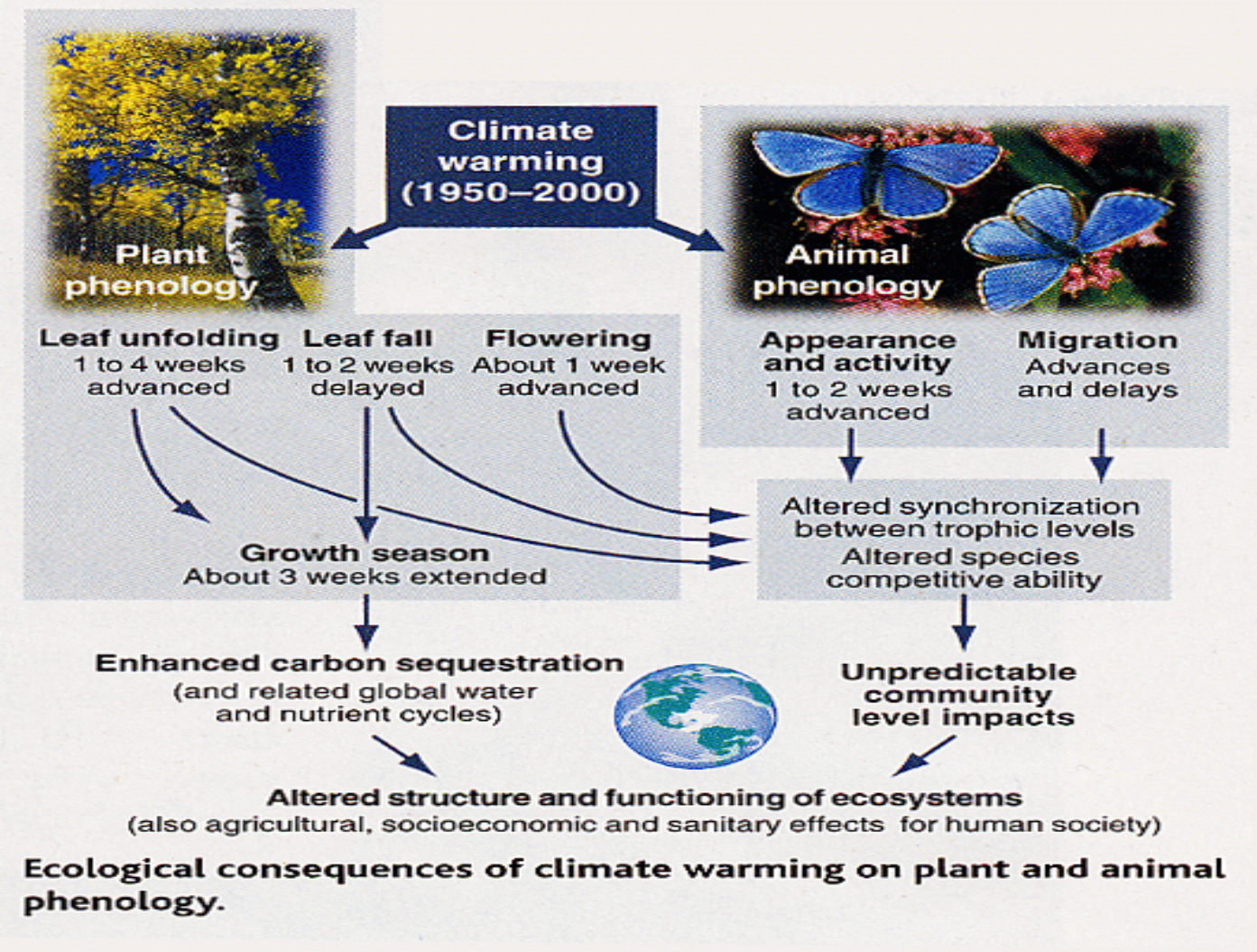
  - Deforesting lands in Central Africa affects precipitation in the upper and lower U.S. Midwest

www.sciencedaily.com/.../ 09/050918132252.htm

Phenological Changes

- Life-cycles of plants and animals have been affected by global change
- Temperatures affecting plants growing season, flowering time and timing of pollination by insects have all been altered
- Studies already showing
  - Mediterranean deciduous plants now leaf 16 days earlier and fall 13 days later than 50 years ago
  - Plants in temperate zones flowering time occurring earlier in the season
  - Growing season increased in Eurasia 18 days and 12 days in N. America over past two decades

Phenological Changes



Ecological consequences of climate warming on plant and animal phenology.

Penuelas J and Filella I 2001. *Response to a warming world*. Science 294: 793 – 795

Conservation Thoughts

- Artificial seed dispersal and transplantation into climatically suitable regions
  - May help in preserving vegetation under stress
  - Problem: soil in new areas unsuitable
- Massive reforestation to help get rid of added CO_2 brought on by man
  - Problem: it's estimated to keep up with emissions efforts will need to be doubled or tripled costing hundreds and millions of dollars
  - Believed to take up to 100 years to reforest 40% of the U.S. forest land
- New technologies of: plant breeding, bioengineering (i.e. Toyota and the cherry shrub), fertilization, irrigation, may aid in migration
- Social, economic and political needs must be addressed or any conservation efforts will fail

Questions

1. What are 6 major terrestrial ecosystems?
2. Climate has always changed and plants have been able to migrate with these changes. Why is modern climate change posing so many problems?
3. What are some conservation efforts being investigated to prevent plant species from extinction?
4. What 4 major things influence geographic distribution of terrestrial biomes?

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