The Ozone Layer

- Located in the stratosphere at 17 to 30 km above sea level
- Contains much of the atmosphere's small amount of ozone
- Acts as a global sunscreen, keeping about 95% of the sun's harmful UV radiation (UV-A and UV-B) away

How is Ozone Formed?

- Through the interaction of oxygen gas (O_2) and ultraviolet radiation (UV) emitted by the sun

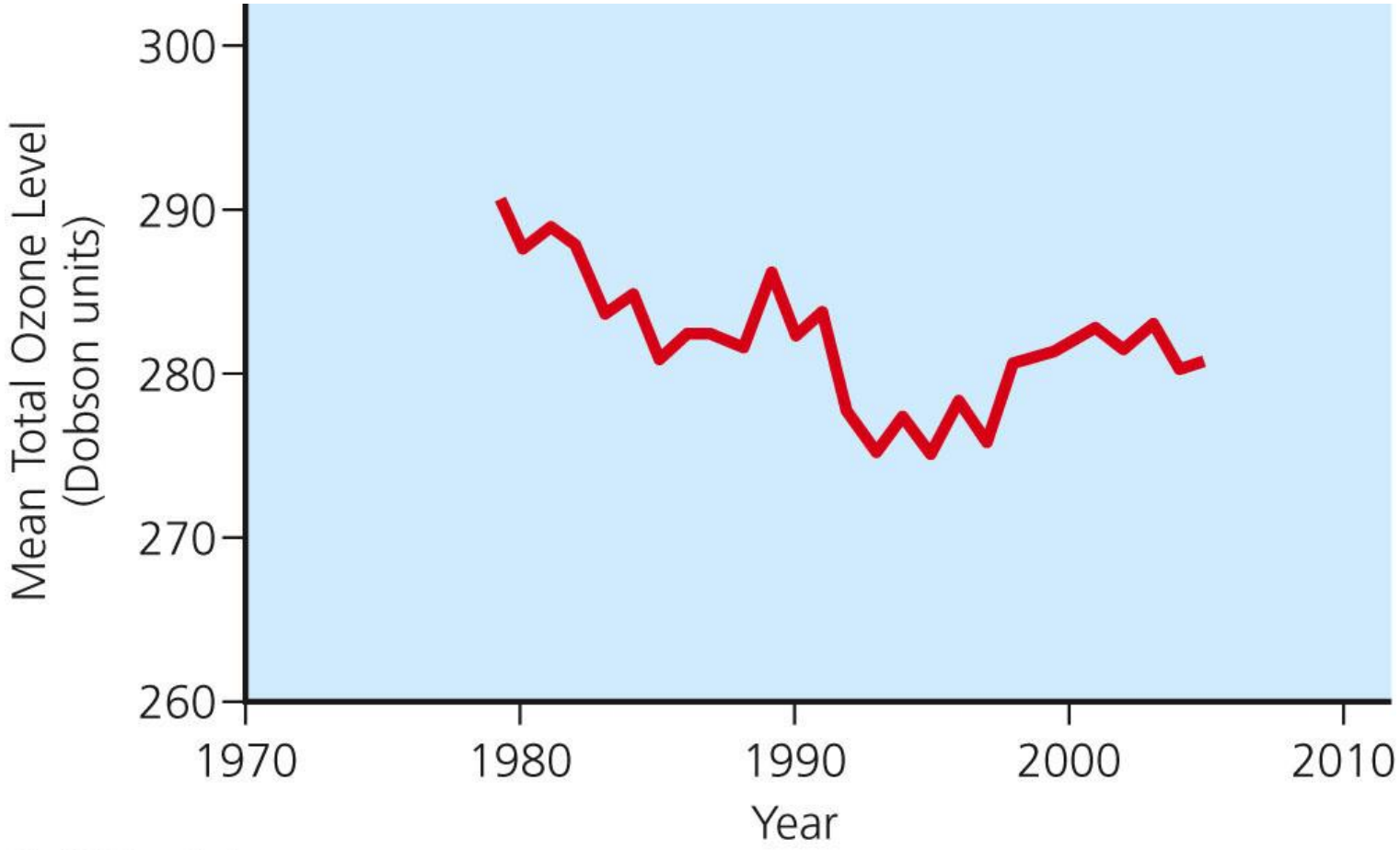
$$\mathbf{3\ O_2 + UV \leftrightarrow 2\ O_3}$$

Ozone Depletion

- Seasonal depletion (thinning) of ozone concentrations in the stratosphere above Antarctica and the Arctic
- Lower overall thinning everywhere except over the tropics

Ozone Depletion

Global Average Total Ozone Values in the Stratosphere (1979–2005)



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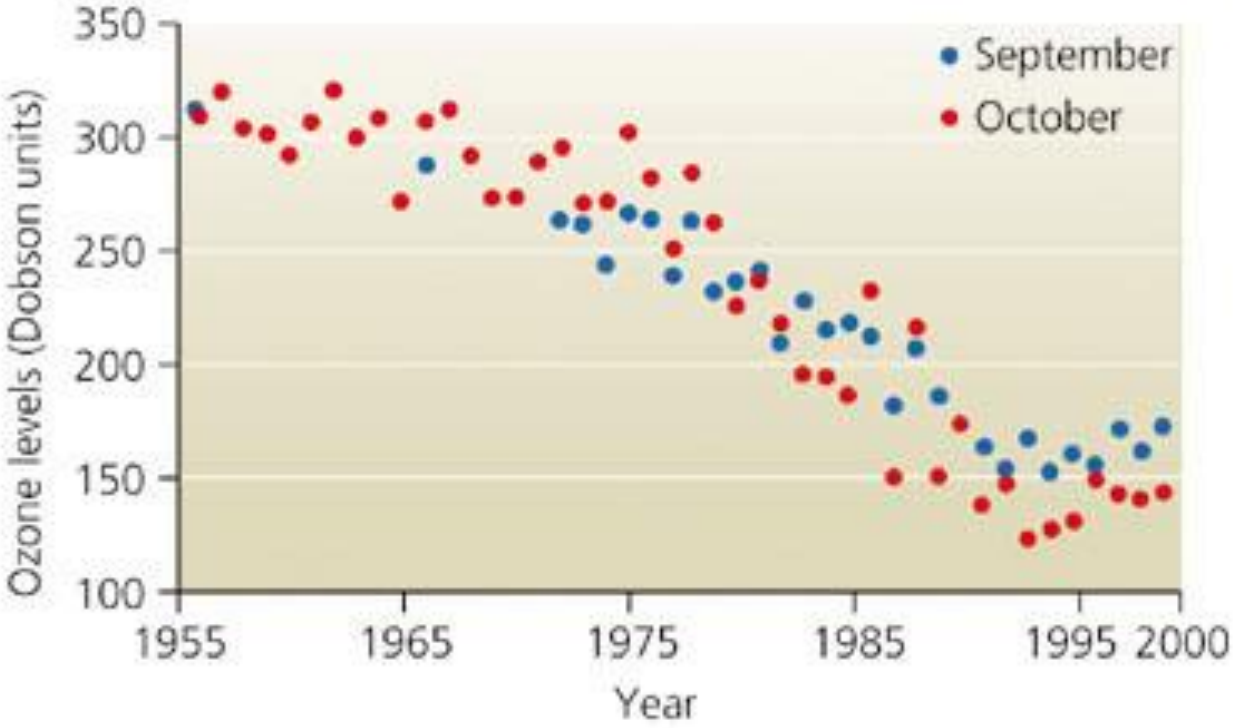
Ozone Depletion

- Each year, 40 to 50% of the ozone in the upper stratosphere over Antarctica (100% in some places) disappears in October and November.
- When this seasonal thinning ends, huge masses of ozone-depleted air above Antarctica flow northward, lingering for a few weeks above Australia, New Zealand, South Africa and South America; raises damaging UV-B levels 3 – 20%!!

Ozone Depletion



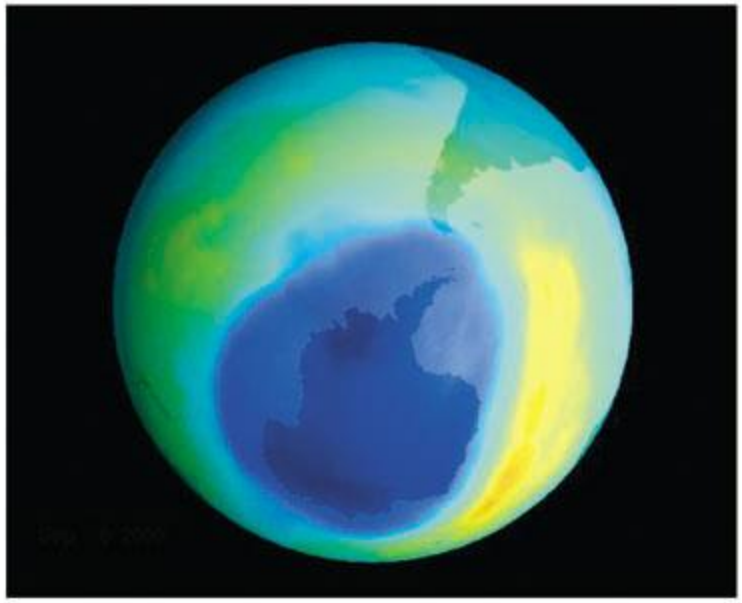
(a) Monthly mean ozone levels at Halley Bay, Antarctica

Ozone Depletion

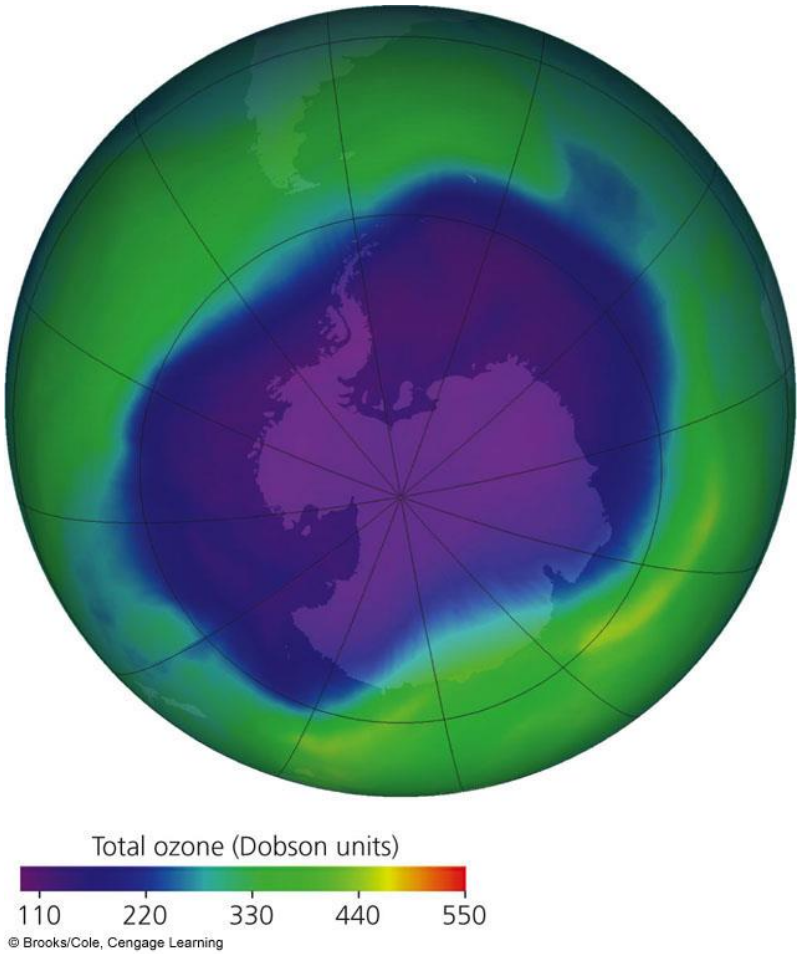
- Observed loss of ozone referred to as “ozone hole”
- More accurately “ozone thinning” as ozone depletion varies with altitude and location

Ozone Depletion

Massive Ozone Thinning over Antarctica in 2007



(b) The "ozone hole" (blue) over Antarctica, September 2000



Ozone Depletion

- Similar, usually less severe thinning (11 to 38%; compared to ca. 50% over Antarctica) over the Arctic from February to June

Chlorofluorocarbons (CFCs)

- First CFC discovered in 1930 by Thomas Midgley, Jr., a General Motors chemist
- Similar compounds later developed by chemists to create a family of compounds known as CFCs or Freons

Chlorofluorocarbons (CFCs)

- Thought to be dream chemicals because they are
  - chemically un-reactive.
  - odorless.
  - nonflammable.
  - nontoxic.
  - noncorrosive.
  - inexpensive to manufacture.

Chlorofluorocarbons (CFCs)

- Uses of CFCs
  - Coolants in air conditioners and refrigerators
  - Propellants in aerosol spray cans
  - Cleaners for electronic parts such as computer chips
  - Fumigants for granaries and ship cargo holds
  - Also used to fill tiny bubbles in plastic foam used for packaging and insulation

Ozone Depletion

- In 1974, Sherwood Rowland and Mario Molina of the University of California, Irvine, indicated that chlorofluorocarbons (CFCs) and other ozone-depleting chemicals were lowering the average concentration of ozone in the stratosphere!!

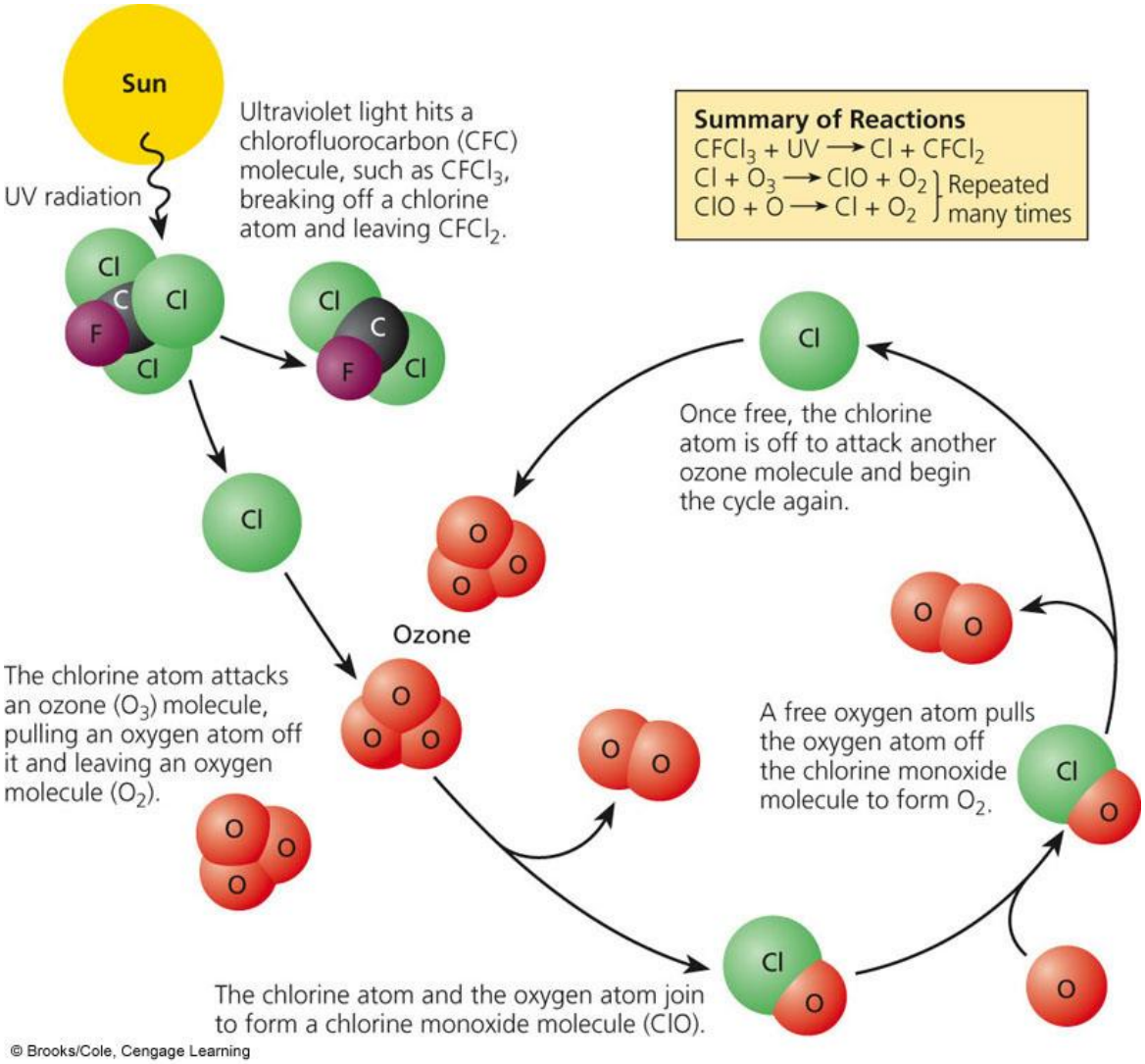
Ozone Depletion

- Other ozone-depleting chemicals include
  - halons and hydrobromofluorocarbons (HBFCs) used in fire extinguishers.
  - methyl bromide, a widely used fumigant.
  - hydrogen chloride emitted into the stratosphere by space shuttles.
  - some cleaning solvents such as carbon tetrachloride.

Ozone Depletion

- Rowland and Molina 1974; Nobel Prize in Chemistry 1995
  - CFCs are persistent in the atmosphere; once in the atmosphere, they remain there.
  - CFCs rise into the stratosphere over 11-20 years.
  - In the stratosphere, they break down under high-energy UV radiation; Halogens produced accelerate the breakdown of ozone to oxygen gas.
  - Each CFC molecule can last 65-385 years, depending on its type.

Ozone Depletion



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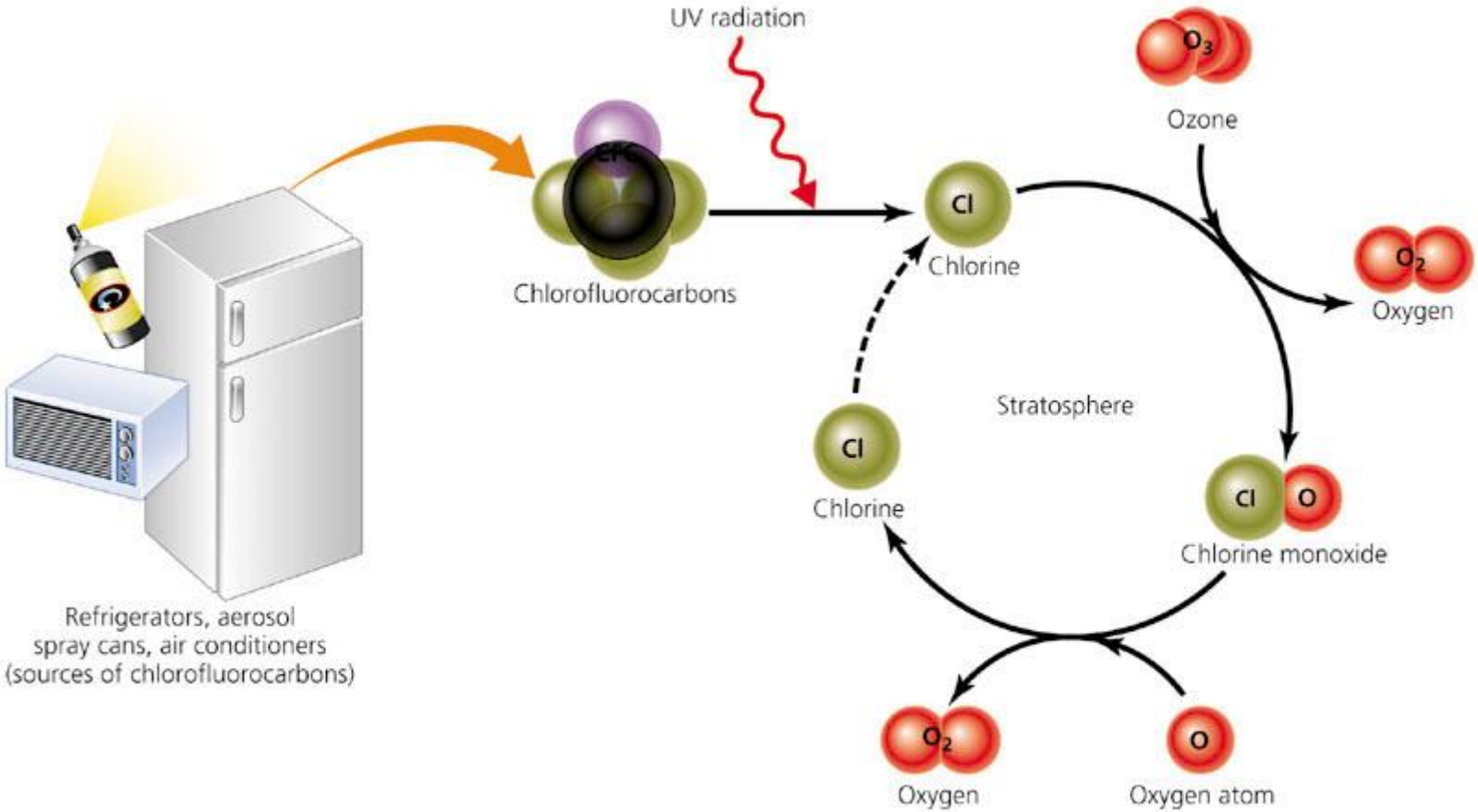
Ozone Depletion



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Ozone Depletion

- Arctic unlikely to develop the large-scale ozone thinning found over the Antarctic based on models
- Ozone depletion over the Arctic and Antarctic predicted to be the worst between 2010 and 2019!!

Ozone Depletion

- Ozone depletion in the stratosphere poses a serious threat to
  - humans.
  - other animals.
  - some primary producers (mostly plants).

NATURAL CAPITAL DEGRADATION

Effects of Ozone Depletion

Human Health

- Worse sunburns
- More eye cataracts
- More skin cancers
- Immune system suppression

Food and Forests

- Reduced yields for some crops
- Reduced seafood supplies from reduced phytoplankton
- Decreased forest productivity for UV-sensitive tree species

Wildlife

- Increased eye cataracts in some species
- Decreased populations of aquatic species sensitive to UV radiation
- Reduced populations of surface phytoplankton
- Disrupted aquatic food webs from reduced phytoplankton

Air Pollution and Materials

- Increased acid deposition
- Increased photochemical smog
- Degradation of outdoor paints and plastics

Global Warming

- While in troposphere, CFCs act as greenhouse gases

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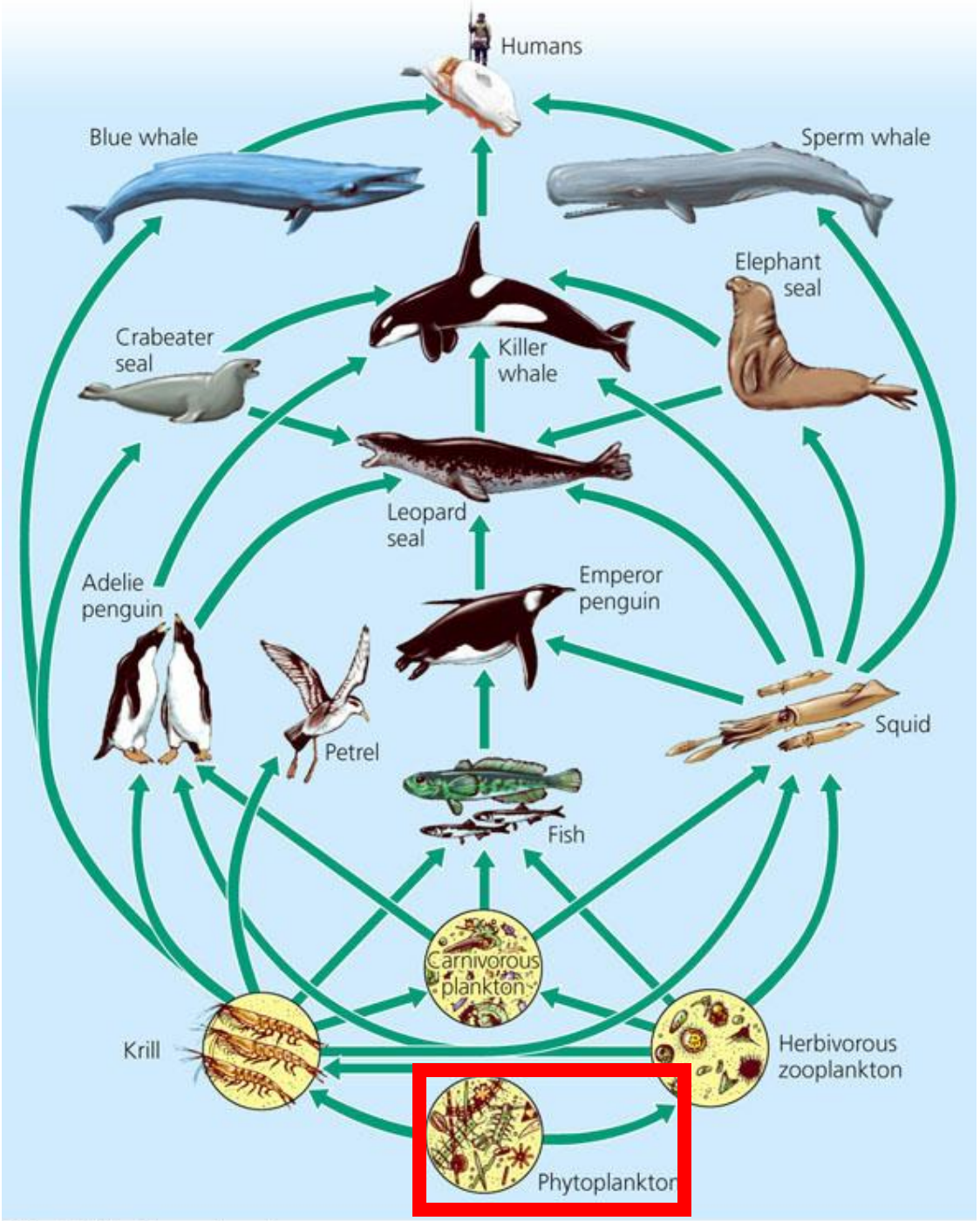
Ozone Depletion

Why should we worry about ozone depletion?

- Biologically damaging UV-A and UV-B radiation will reach the earth, giving people more eye cataracts, worse skin burns and more skin cancer!!
- UV radiation may impair or destroy phytoplankton, especially in Antarctic waters!!

Simplified food web in the Antarctic



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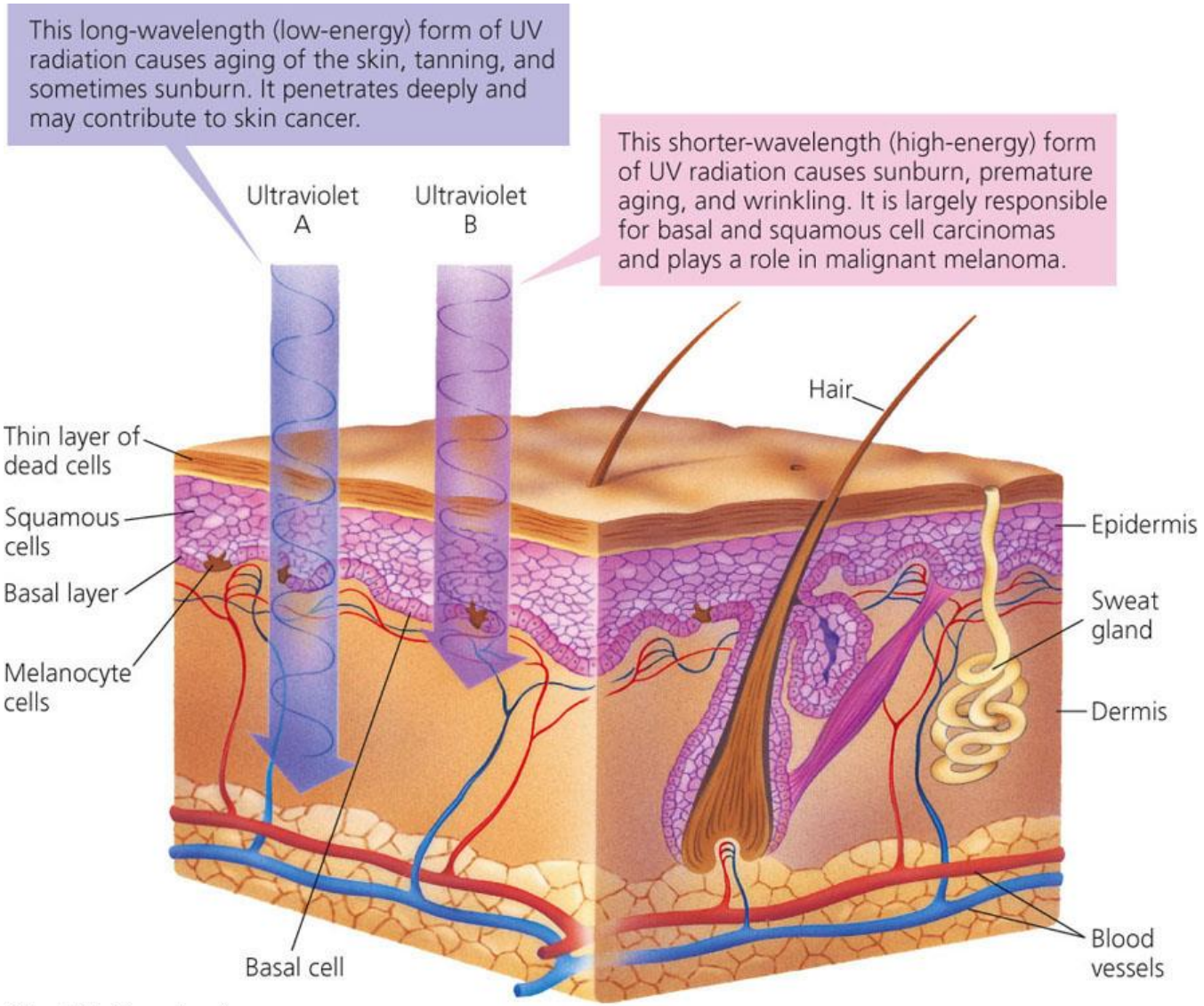
Ozone Depletion



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Ozone Depletion

Squamous Cell Carcinoma

Arising from cells in the upper layer of the epidermis, this cancer is also caused by exposure to sunlight or tanning lamps. It is usually curable if treated early. It grows faster than basal cell carcinoma and can spread to other parts of the body (metastasize).

Basal Cell Carcinoma

The most common skin malignancy usually is caused by excessive exposure to sunlight or tanning lamps. It develops slowly, rarely metastasizes and is nearly 100% curable if diagnosed early and treated properly.

Melanoma

This deadliest of skin cancers involves melanocyte cells, which produce pigment. It can develop from a mole or on blemished skin, grows quickly, and can spread to other parts of the body (metastasize).

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WHAT CAN YOU DO?

Reducing Exposure to UV Radiation

- Stay out of the sun, especially between 10 A.M. and 3 P.M.
- Do not use tanning parlors or sunlamps.
- When in the sun, wear protective clothing and sunglasses that protect against UV-A and UV-B radiation.
- Be aware that overcast skies do not protect you.
- Do not expose yourself to the sun if you are taking antibiotics or birth control pills.
- When in the sun, use a sunscreen with a protection factor of at least 15.
- Examine your skin and scalp at least once a month for moles or warts that change in size, shape, or color and sores that keep oozing, bleeding, and crusting over. If you observe any of these signs, consult a doctor immediately.

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Ozone Depletion
What Shall We Do?

- Immediately stop producing ozone-depleting chemicals
- According to models, even with immediate and sustained action, 60 – 100 years for recovery of the ozone layer
- Global warming in troposphere makes stratosphere cooler; slower rate of ozone repair

Ozone Depletion
What Shall We Do?

- Montreal Protocol (1987; 36 countries): Cut emissions of CFCs but not other ozone-depleting chemicals by about 35% between 1989 and 2000
- Copenhagen Protocol (1992; 93 countries): Amendment that accelerates the phase-out of key ozone depleting chemicals
- Ozone protocols now signed by 191 countries:
  - Ozone levels to return to 1980 levels by 2068
  - Ozone levels to return to 1950 levels by 2108
  - Prevention is the key

Ozone Depletion
What Shall We Do?

- Substitutes for CFCs are available; more are being developed.
- HCFC-22
  - Most widely used substitute; causes some ozone depletion
  - Also warms the troposphere (10,000 times more than carbon dioxide per molecule)
  - To be phased out in 2020 in developed countries and 2030 in developing countries