MODULE- III

# EFFECTS OF AIR POLLUTION

*Prepared by*
*Bibhabasu Mohanty*
*Dept. of Civil Engineering*
*SALITER, Ahmedabad*

# Contents…

Effects of Air Pollution on human beings, plants and animals and Properties. Global effects- Green house effect, Ozone depletion, heat island, dust storms, Automobile pollution sources and control, Photochemical smog, Future engines and fuels

# On human being...

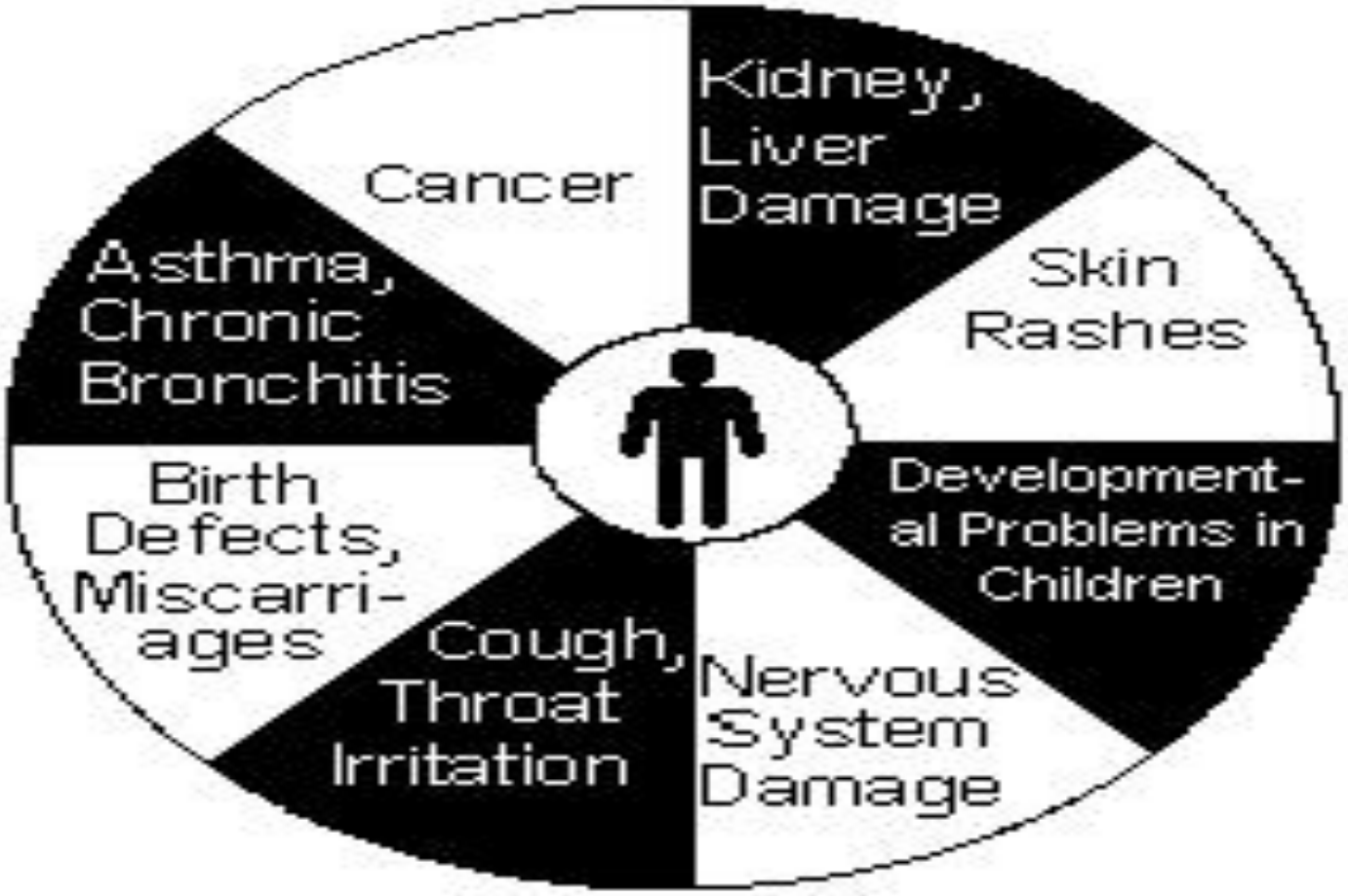
# Introduction

- ✓ Air pollution : one of the greatest "**ENVIRONMENTAL EVIL**"
- ✓ The air we breathe has not only **LIFE SUPPORTING** properties but also **LIFE DAMAGING** properties.
- ✓ An average man breathes **22,000 times** a day and takes in **16 kg of air** each day.
- ✓ All the impurities in the inhaled air do not necessarily cause harm. Some may be harmful when present in air in small concentration and others only if they are present in high concentration.

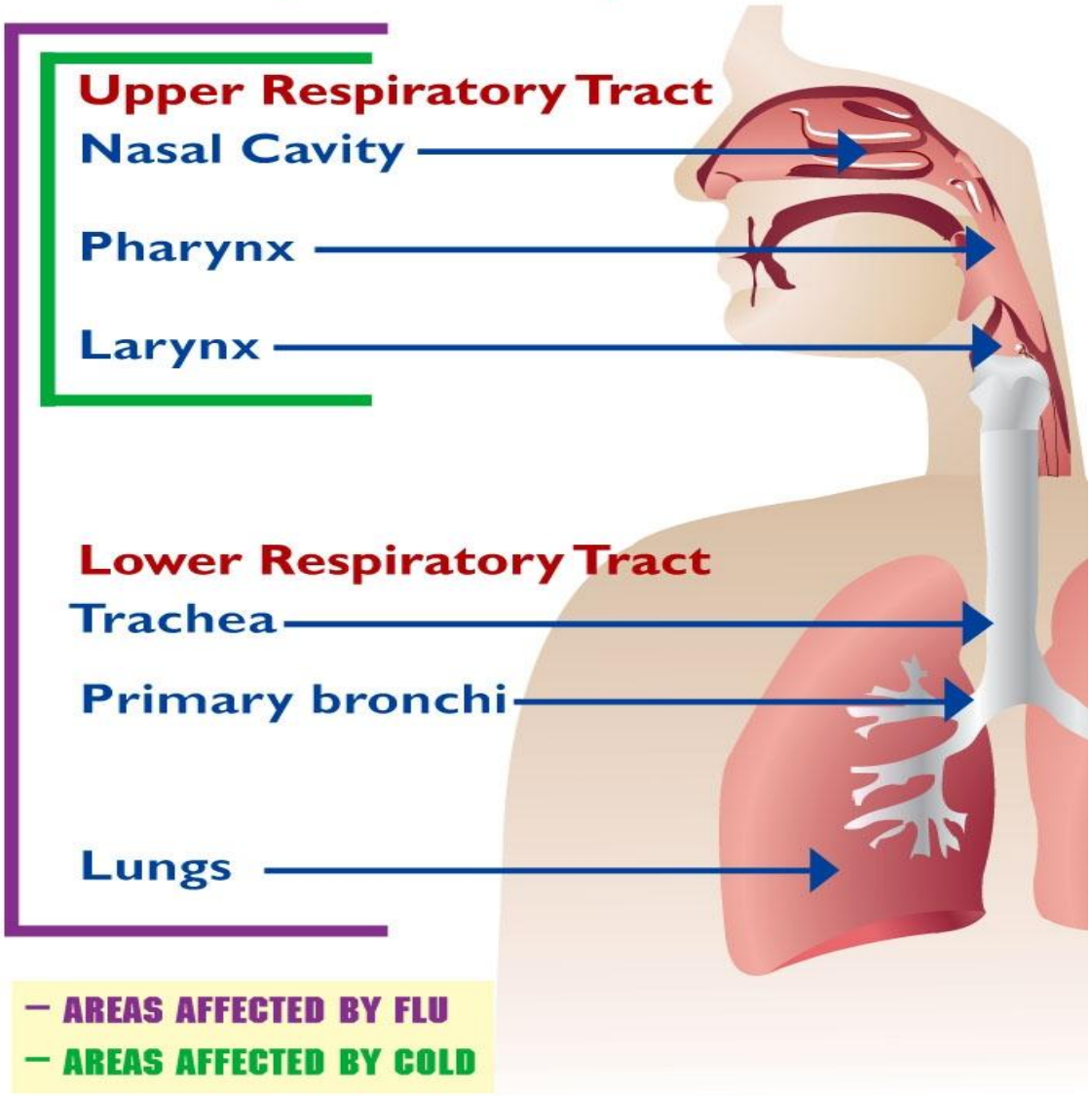
# Factors affecting human health

- ✓ Nature of the pollutants
- ✓ Concentration of the pollutants
- ✓ Duration of exposure
- ✓ State of health of the receptor
- ✓ Age group of the receptor

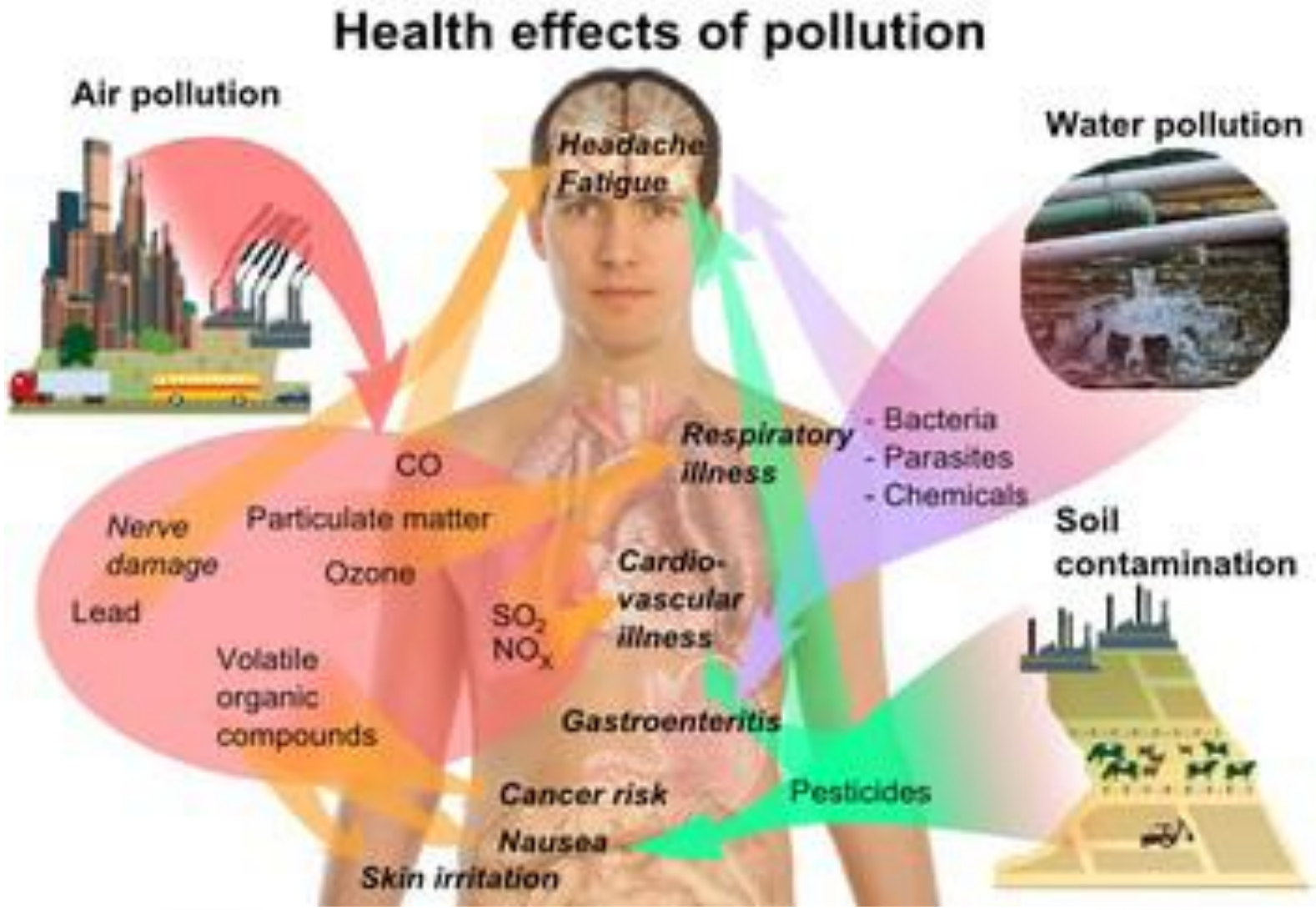
# Target organ systems of air pollution



# Respiratory Tract



# Diseases caused by air pollutants



# Effects of Air Pollution

- ✓ Reduced lung functioning
- ✓ Irritation of eyes, nose, mouth and throat
- ✓ Asthma attacks
- ✓ Respiratory symptoms such as coughing and wheezing
- ✓ Increased respiratory disease such as bronchitis
- ✓ Reduced energy levels

- ✓ Headaches and dizziness
- ✓ Disruption of endocrine, reproductive and immune systems
- ✓ Neuro behavioural disorders
- ✓ Cardiovascular problems
- ✓ Cancer
- ✓ Premature death

# Particulate Matter effect

- ✓ Health effects
  - Wheezing and coughing
  - Heart attacks and death
- ✓ TSP (Total Suspended Particles)
  - In presence of $SO_2$, direct correlation between TSP and hospital visits for bronchitis, asthma, emphysema, pneumonia, and cardiac disease
  - ~60,000 deaths from PM
  - 1% increase in mortality for every 10 $mg/m^3$ increase in PM
    - Respiratory mortality up 3.4% for the same
    - Cardiovascular mortality up 1.4% for the same

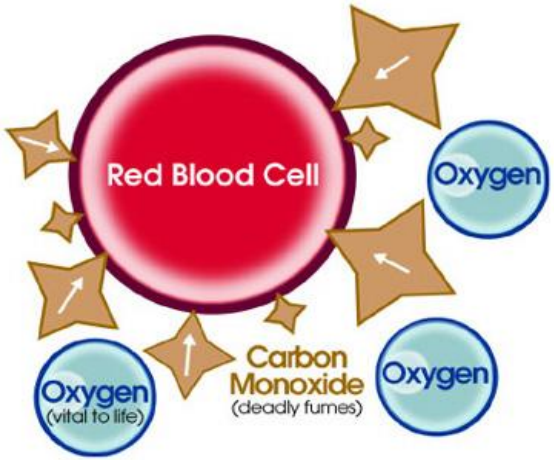
- ✓ $PM_{10}$ (<10 μm, coarse (2.5-10 μm) and fine particles)
  - Anything larger deposited in the HAR (nasal-pharangycal)
- ✓ $PM_{2.5}$ (<2.5 μm, fine particles)
  - Most serious health effects in alveolar/gas exchange region

    → shift in regulation focus
  - May adsorb chemicals & intensify their effects
  - Toxic or carcinogenic – pesticides, lead, arsenic, radioactive material
    - 8% increase in lung cancer for each 10 $\mu g/m^3$ increase of $PM_{2.5}$

# Carbon Monoxide effect

- ✓ Colorless, odorless, tasteless gas
  → "Silent Killer"
- ✓ Review…
  - Cause: incomplete combustion
  - Source: transportation sector, energy production, residential heating units, some industrial processes
- ✓ Ambient concerns addressed by NAAQS

- ✓ Reacts with hemoglobin in blood
  - Forms carboxyhemoglobin (HbCO) rather than oxyhemoglobin ($HbO_2$)
  - Prevents oxygen transfer




- ✓ Toxic effects on humans
  - Low-level: cardiovascular and neurobehavioral
  - High-level: headaches/nausea/fatigue to possible death
  - Oxygen deficient people esp. vulnerable (anemia, chronic heart or lung disease, high altitude residents, smokers)
    - Cigarette smoke: 400-450 ppm; smoker's blood 5-10% HbCO vs 2% for non-smoker

- ✓ Concern in homes especially - Install CO monitor!
  - No indoor home regulations
    - >70 ppm → flu-like symptoms (w/out fever)
    - 150-200 ppm → disorientation, drowsiness, vomiting
    - >300 ppm → unconsciousness, brain damage, death
  - 500 Americans die/year from unintentional CO poisoning
  - **Treatment: fresh air, oxygen therapy, hyperbaric chamber**

# Ozone effect

- ✓ Cause: product of photochemical reactions
- ✓ Source: cars, power plants, combustion, chemical industries
- ✓ Acute Health effects
  - Severe E/N/T (ear/nose/throat) irritation
  - Eye irritation at 100 ppb
  - Interferes with lung functions
    - Coughing at 2 ppm
- ✓ Chronic Health Effects
  - Irreversible, accelerated lung damage

# $No_x$ effect

- ✓ Cause: Fuel combustion at high temps
- ✓ Source: mobile and stationary combustion sources
- ✓ Prolonged exposure → pulmonary fibrosis, emphysema, and higher LRI (lower respiratory tract illness) in children
- ✓ Toxic effects at 10-30 ppm
  - Nose and eye irritation
  - Lung tissue damage
    - Pulmonary edema (swelling)
    - Bronchitis
  - Pneumonia
  - Aggravate existing heart disease

# $So_x$ effect

- ✓ Cause: Burning fuel that contains sulfur
- ✓ Source: Electric power generation, diesel trucks
- ✓ Gas and particulate phase
- ✓ Soluble and absorbed by respiratory system
- ✓ Short-term intermittent exposures
  - Bronchoconstriction (temporary breathing difficulty)
  - E/N/T irritation
  - Mucus secretion
- ✓ Long-term exposures
  - Respiratory illness
  - Aggravates existing heart disease
- ✓ Intensified in presence of PM
  - London issues were combination of the two

# Lead (Pb) effect

- ✓ Source: burning fuels that contain lead (phased out), metal processing, waste incinerators
- ✓ Absorbed into blood; similar to calcium
- ✓ Accumulates in blood, bones, muscles, fat
  - Damages organs – kidneys, liver, brain, reproductive system, bones (osteoporosis)
  - Brain and nervous system – seizures, mental retardation, behavioral disorders, memory problems, mood changes,
    - Young children - lower IQ, learning disabilities
  - Heart and blood – high blood pressure and increased heart disease
  - Chronic poisoning possible

# Mercury effect

- ✓ Elemental Hg inhaled as a vapor, absorbed by lungs
- ✓ Cause: vaporized mercury
- ✓ Sources: coal combustion, accidental spill, mining
- ✓ Effects: Nervous system (acute, high), respiratory system (chronic, low), kidneys, skin, eyes, immune system; Mutagenic properties
- ✓ Symptoms
  - Acute: chills, nausea, chest pains/tightness, cough, gingivitis, general malaise
  - Chronic: weakness, fatigue, weight loss, tremor, behavioral changes

# Dioxins effects

- ✓ Generic term for several chemicals that are highly persistent in the environment
  - chlorinated dibenzo-p-dioxins (CDDs)
  - chlorinated dibenzofurans (CDFs)
  - certain polychlorinated biphenyls (PCBs)
- ✓ Cause: burning chlorine-based compounds with hydrocarbons
- ✓ Sources: waste incinerator

- Varying toxicity
  - Generally problems with high exposures
  - Exact effects of low exposures not really known

- Health Effects
  - Carcinogenic
    - Some are "known human carcinogen" (2,3,7,8 tetrachlordibenzo-p-dioxin, TCDD)
    - Others are "reasonably anticipated to be a Human Carcinogen"
  - Reproductive and developmental effects
  - Chloracne

# Bioaerosols effect

- ✓ Aerosols with organic origin
  - Non-viable: pollen, dander, insect excreta, sea salt
  - Viable: microorganisms
- ✓ Cause: aerosolization of organic material
- ✓ Sources:
  - Human: sneezing, coughing
  - Non-human: wind, waves, WWTP
- ✓ Health Effects: allergies (pollen) to death (pathogenic organisms)
  - Pathogenic – Minimum Infectious Dose

- ✓ Allergies
  - Pollen, dander, fungi (spores)
- ✓ Airborne transmission of disease
  - Bird flu, SARS, Legionnella (pneumonia)
  - Indoor Air Quality
    - Ventilation Systems – moist ductwork, protection, recycled air
    - Office Buildings – Sick Building Syndrome
      - Hospital (nosocomial)
    - Biological Warfare
      - Anthrax, Ebola virus

# On plants . . .

# Introduction

- ✓ Have an adverse effect on plants
- ✓Cause a widespread damage to natural vegetation and economic crops
- ✓ Many species are susceptible to damage even at low concentrations
- ✓Gaseous pollutants are actively metabolized by some plants and these plants are employed as indicators of air pollutants

# Pollutants affecting plants

- ✓ $SO_x$
- ✓ $NO_x$
- ✓ Ozone
- ✓ PAN
- ✓ Mercury
- ✓ Hydrogen Sulphide
- ✓ Smog, etc..

Forms of damages to leaves

- Necrosis:

  killing or collapse of tissue

- Chlorosis:

  loss or reduction of chlorophyll resulting in fading of the leaf's green color to yellowish or pale green.

- Abscission:

  dropping of leaves

- Epinasty:

  downward curvature of leaf due to the higher rate of growth on the upper surface

Kinds of injury to plants

- Acute injury
- Chronic injury
- Growth or Yield retardation

**Acute injury:**

short-time to high concentration occur under fumigation conditions. Effects are noted within few hours to few days- make visible markings on the leaves

**Chronic injury:**

long-term to low concentrations

**Growth or Yield retardation:**

effect on growth of plants without visible markings. Usually suppression of growth or yield occurs

# $So_x$ effect

**Acute injury**

- ✓ The symptoms appear as 2-sided (bifacial) lesions that usually occur between the veins and occasionally along the margins of the leaves.
- ✓ The color of the necrotic area can vary from a light tan or near white to an orange-red or brown depending on the time, the plant species affected and weather conditions.

**Chronic injury**

- ✓ The symptoms appear as a yellowing or chlorosis of the leaf, and occasionally as a bronzing on the under surface of the leaves.

**Other effects are:**

- ✓Cell metabolism disruption (membrane damage, respiration and photosynthetic effects)
- ✓Leaf injury and loss
- ✓Reduced growth and reproduction
- ✓Increase in susceptibility of plants to attacks by insect herbivores

Trees Damaged by Sulfur Emissions

Acute sulfur dioxide injury to raspberry

# $No_x$ effect

- ✓ Seriously injure vegetation at certain concentrations. Effects include:
- ✓ Bleaching or killing plant tissue.
- ✓ Causing leaves to fall.
- ✓ Reducing growth rate.

# PAN effect

- ✓ PAN has more soluble alkyl groups, will be readly taken up by the plants.
- ✓ PAN damage can occur at levels near 0.01ppm for a few hours or even within a few minutes with a levels near 0.1ppm
- ✓ PAN entry into the leaf through stomata. It affects the parenchymatous in the vicinity of stomata.
- ✓ The damage is reflecting in lower and upper surfaces of leaves.

- ✓ Enzymes, phosphoglucomutase and phosphorylase are inhibited by PAN
- ✓ It can inhibit the mobilization of starch in darkness due to suppression of phosphorylase reaction.
- ✓ Also inhibits $CO_2$ fixation during photosynthesis
- ✓ Fatty acid synthesis is affected by PAN due to oxidation of NADPH.

On animals...

- ✓ Toxic pollutants in the air, or deposited on soils or surface waters, can impact wildlife in a number of ways.
- ✓ Like humans, animals can experience health problems if they are exposed to sufficient concentrations of air toxics over time.
- ✓ Air toxics are contributing to birth defects, reproductive failure, and disease in animals.
- ✓ Persistent toxic air pollutants (those that break down slowly in the environment) are of particular concern in aquatic ecosystems.
- ✓ Accumulate in sediments and may biomagnify in tissues of animals.

- ✓ Acid rain (formed in the air) destroys fish life in lakes and streams.
- ✓ Excessive ultraviolet radiation coming from the sun through the ozone layer in the upper atmosphere which is eroded by some air pollutants, may cause skin cancer in wildlife.
- ✓ Ozone in the lower atmosphere may damage lung tissues of animals.

# On Properties…

# Introduction

- ✓ Damage to property important economic aspect of pollution.
- ✓ Damage to property covers corrosion of metals, soiling, eroding of building surface, fading of dyed material, rubber cracking.
- ✓ Deterioration of works of art.

# Mechanisms deterioration

Air pollutants cause damage to materials by five mechanisms:

1. Abrasion
2. Deposition and removal
3. Direct chemical attack
4. Indirect chemical attack
5. Corrosion

## Factors influencing atmospheric deterioration

1. Moisture
2. Temperature
3. Sunlight
4. Air movement

# On building materials

- ✓ Smoke and aerosols adhere to stone, brick and building surface to produce unsightly coatings.
- ✓ SOx in presence of moisture react with limestone and change the color. (Tajmahal)
- ✓ CO2 in presence of moisture produce carbonic acid, which causes leaching problem.
- ✓ Requires additional cleaning expanse.


Discovery


A


B

# On paints

- ✓ Areas high pollution require frequent painting.
- ✓ Pollutants damage protective coating.
- ✓ Common pollutants cause damage are O3, H2S, SO2 and aerosol.
- ✓ H2S cause darkening of surfaces covered with paint containing white lead.

# On textiles

- ✓ SO2 causes deterioration of natural and synthetic textile fibers.
- ✓ Permanent damage to nylon hose.
- ✓ Fading of textile dyes by oxides of nitrogen, ozone.

# On rubber

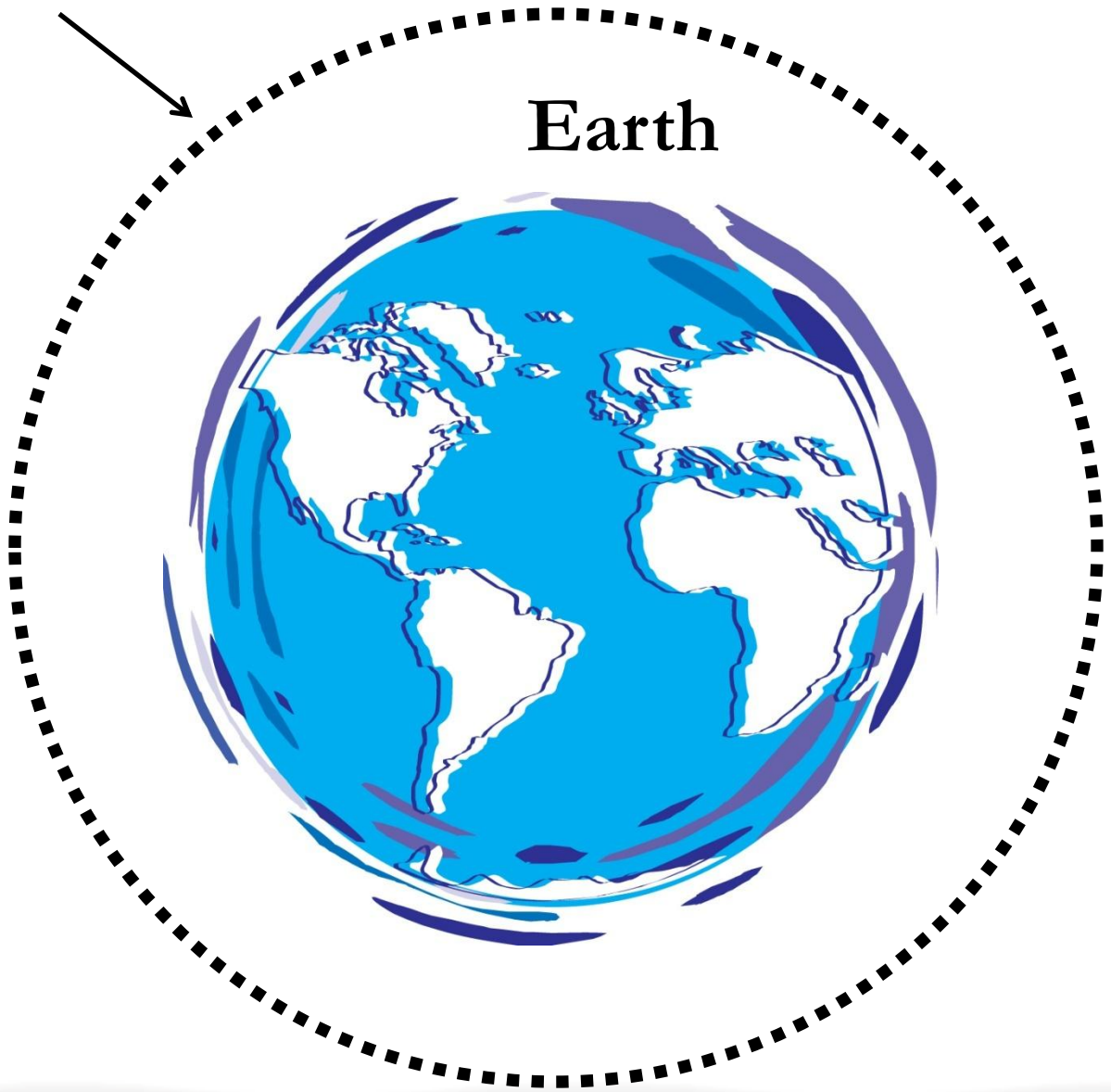
- ✓ Cracking of rubber of side walls of tyres and various forms of electrical insulation.

# On leather

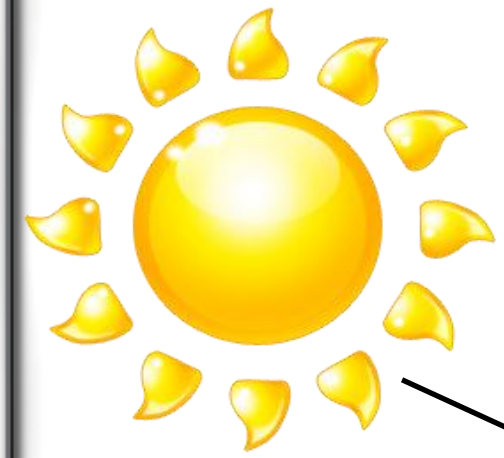
- ✓ $SO_2$ causes leather to lose much of its strength and lastly disintegrate.

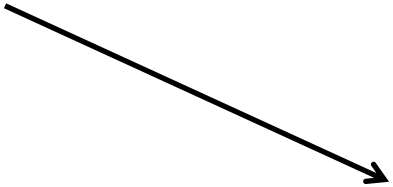
# Green house effect...

gases in the atmosphere

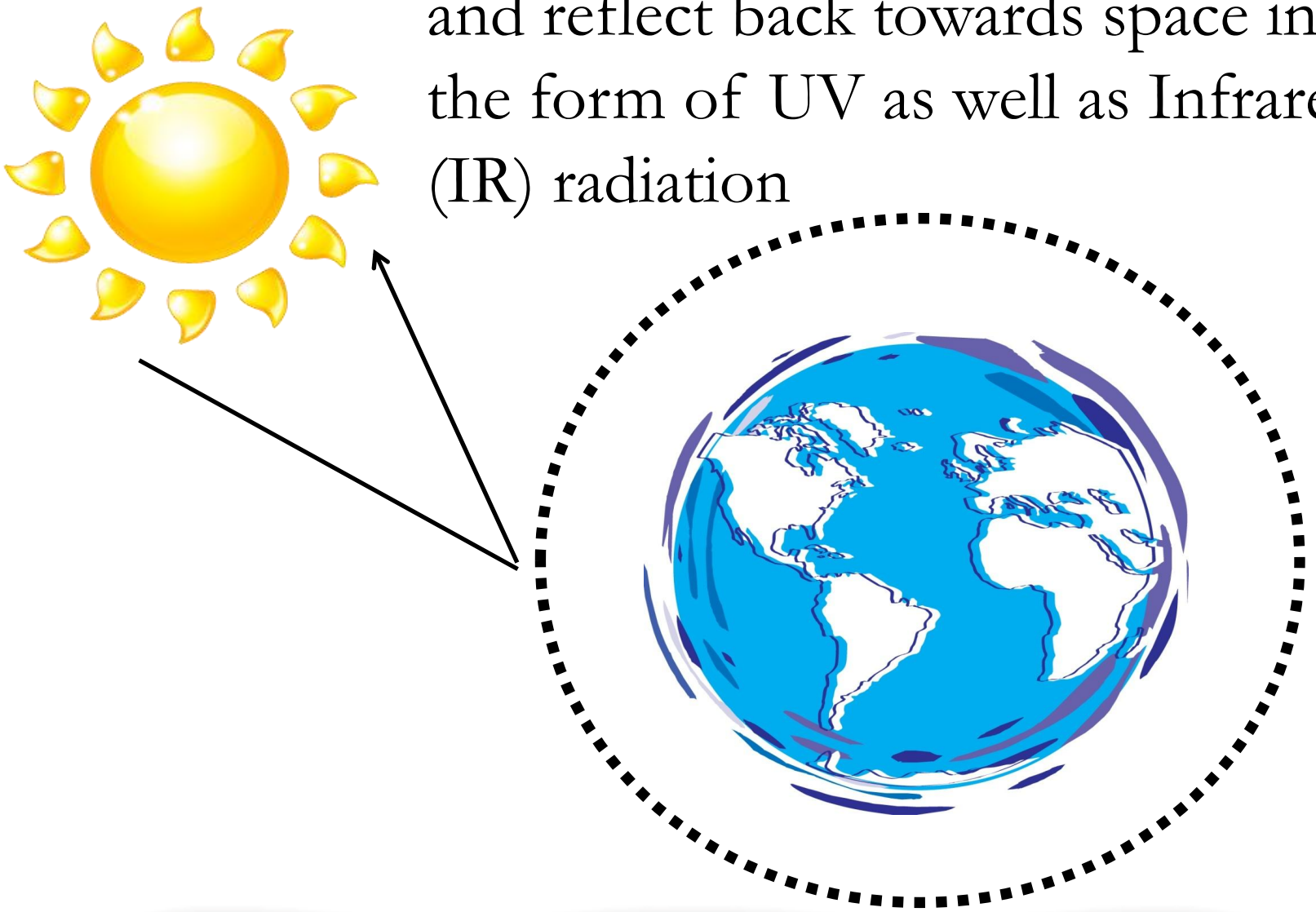


# The sun emits ultraviolet (UV) radiation which hits the earth

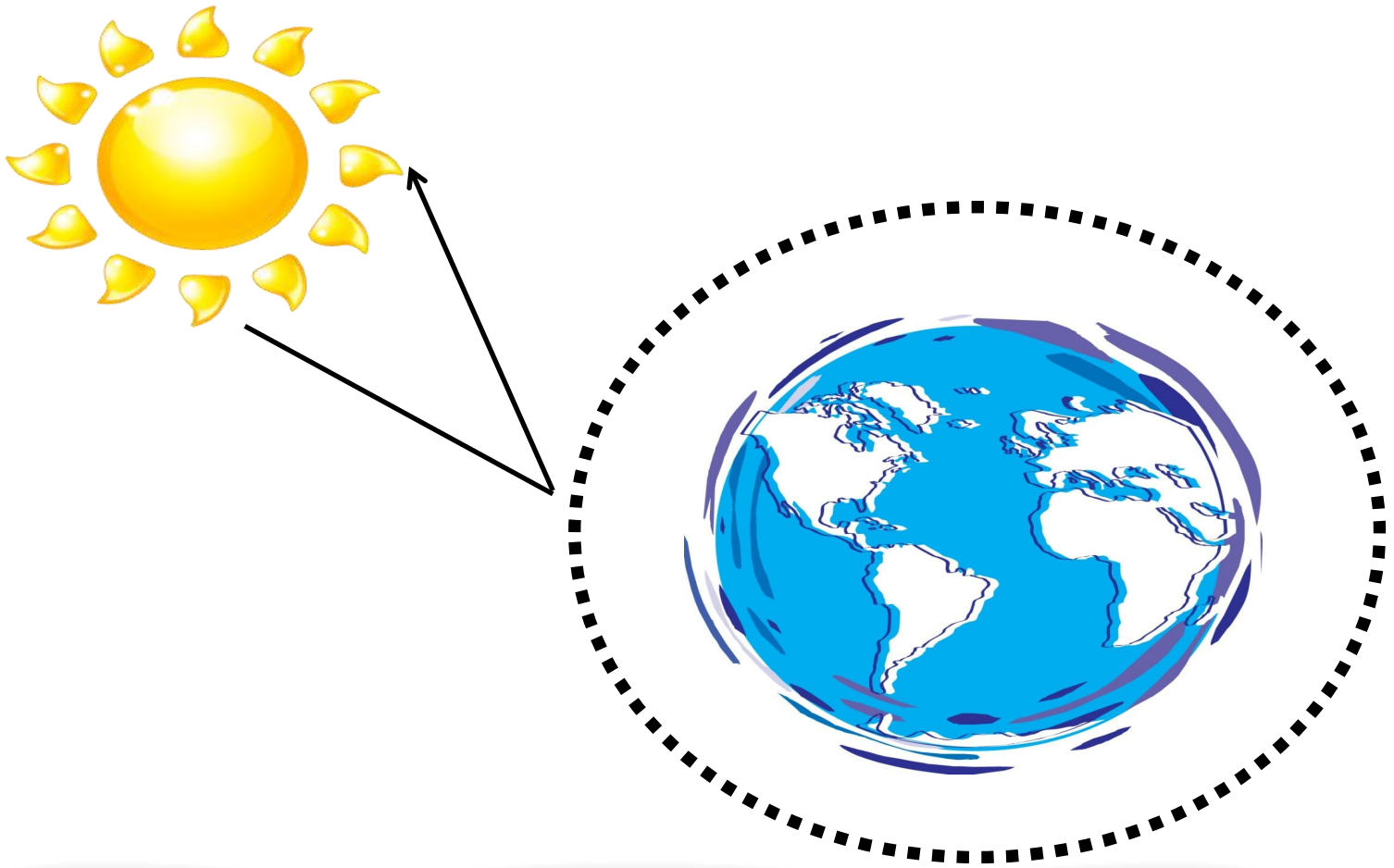




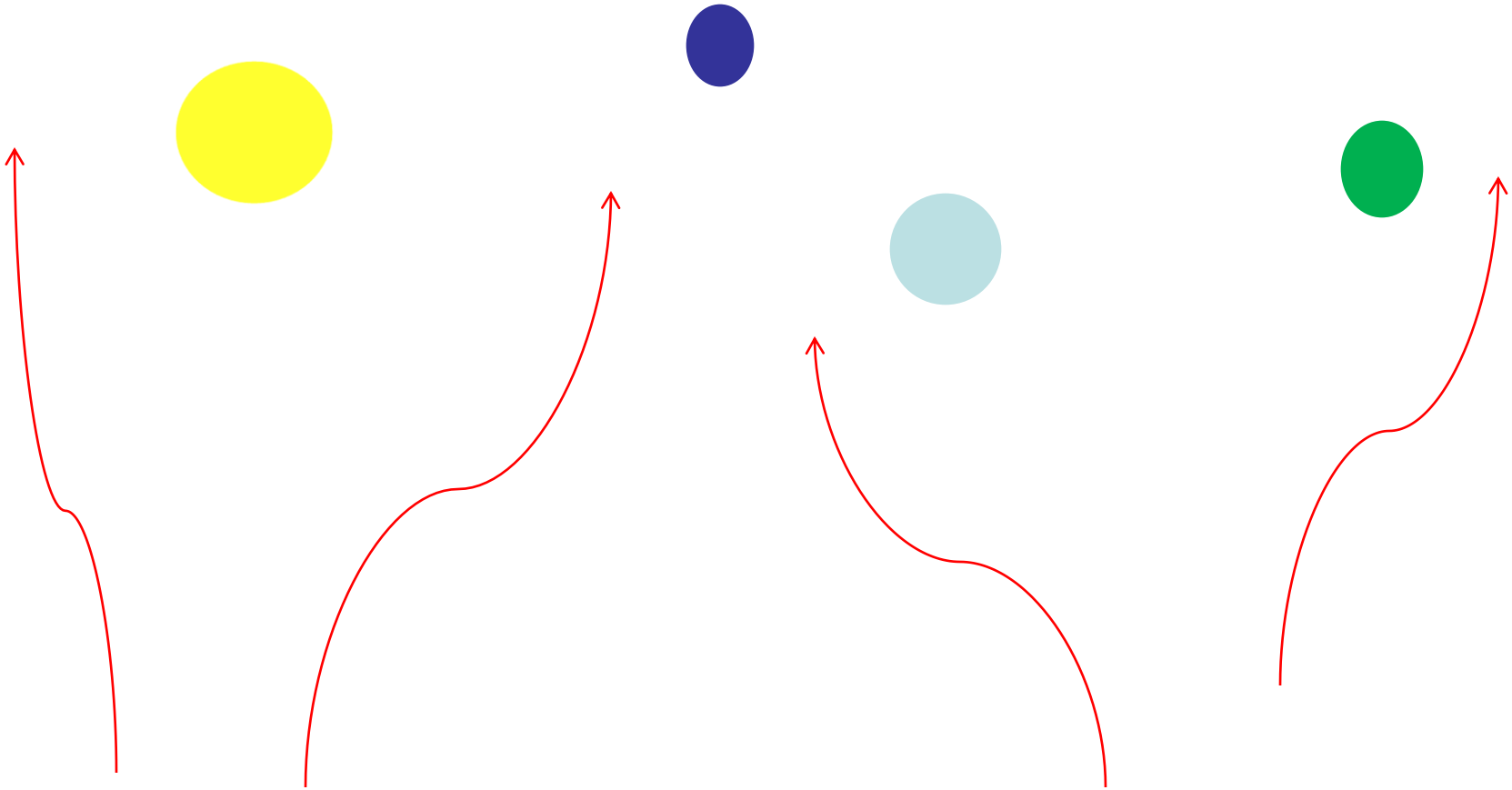
These rays of light hit the earth and reflect back towards space in the form of UV as well as Infrared (IR) radiation



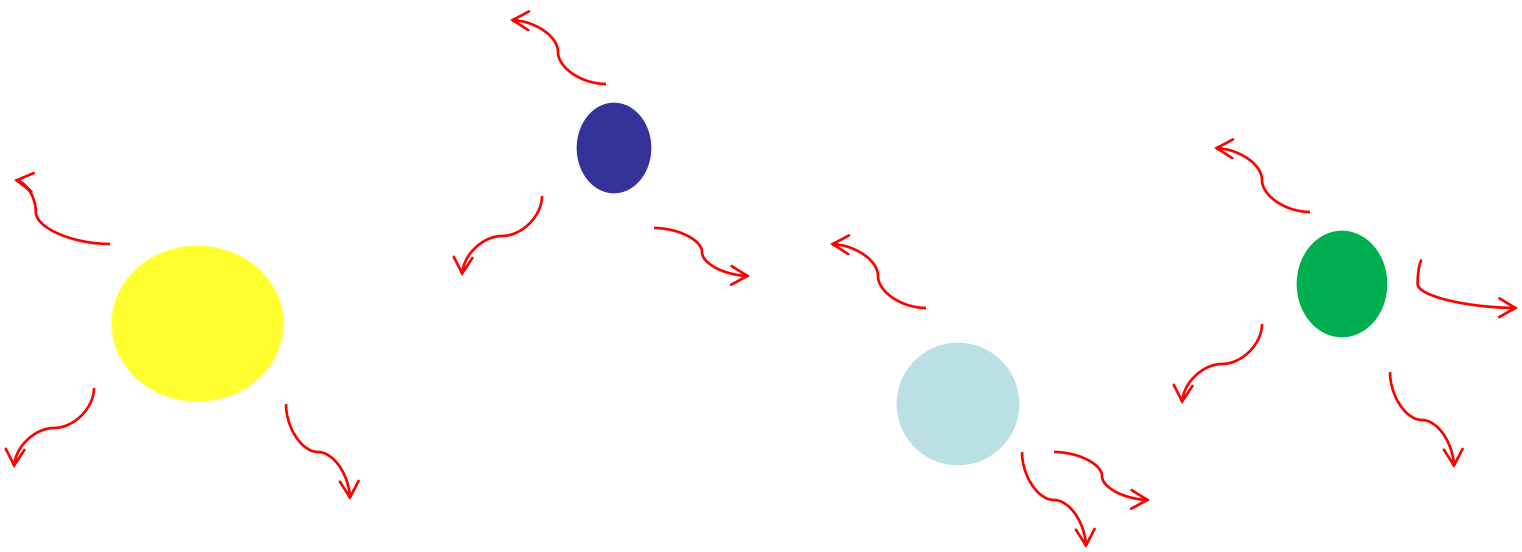
gases in the atmosphere pick up some of the heat from the IR rays and disperse them back into the earth's atmosphere keeping the earth warm enough to sustain life



On a molecular level…



When certain gases in the atmosphere absorb IR Radiation their vibrational modes are excited and vibrate, causing them to collide with other molecules and transfer energy



When the electrons return to their ground state, they re-emit the energy with a frequency equal to the frequency of energy gap between the two levels

Only certain gases do this, just like dogs can hear frequencies that humans cannot because their eardrum vibrates with different wavelengths than ours

# If this didn't happen...

The climate would be an average of 60°F colder and the earth could not sustain life as we know it.

So greenhouse gases are called greenhouse gases because they keep some heat in the atmosphere to sustain life on earth as a greenhouse does to sustain life in the greenhouse when it is cold outside

# Let's find out which atmospheric gases are green house gases

# Hint…

**Greenhouse gas molecules are able to vibrate with the absorption of heat**

# So why do greenhouse gases have such a bad reputation?

# Selected Greenhouse Gases

- ✓ **Carbon Dioxide ($CO_2$)**
  - Source: Fossil fuel burning, deforestation
  - Anthropogenic increase: **30%**
  - Average atmospheric residence time: **500 years**
- ✓ **Methane ($CH_4$)**
  - Source: Rice cultivation, cattle & sheep ranching, decay from landfills, mining
  - Anthropogenic increase: **145%**
  - Average atmospheric residence time: **7-10 years**
- ✓ **Nitrous oxide ($N_2O$)**
  - Source: Industry and agriculture (fertilizers)
  - Anthropogenic increase: **15%**
  - Average atmospheric residence time: **140-190 years**

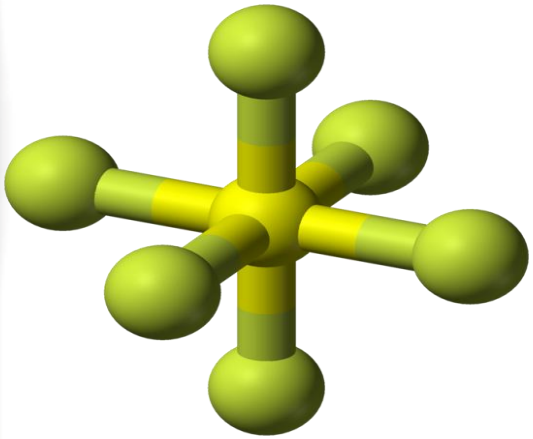
# Natural Versus Enhanced

Climate chemists believe that humans are producing more of the naturally occurring greenhouse gases than the atmosphere can naturally handle from…

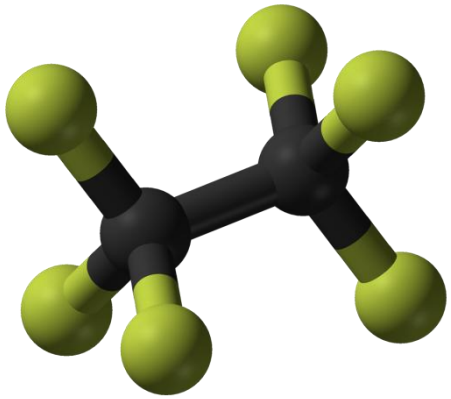
# Anthropogenic


**"That is sooo anthropogenic."**

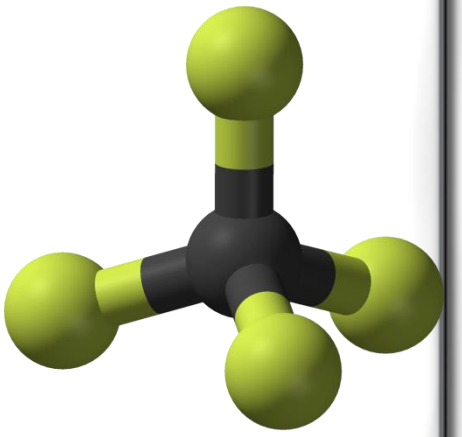
# Some greenhouse gases are not naturally occurring – they are manmade



Sulfur Hexafluoride



Hexafluoroethane



Carbon tetra fluoride

# And Hydro fluorocarbons

Hole in the Ozone Layer?

Which once saved the earth!

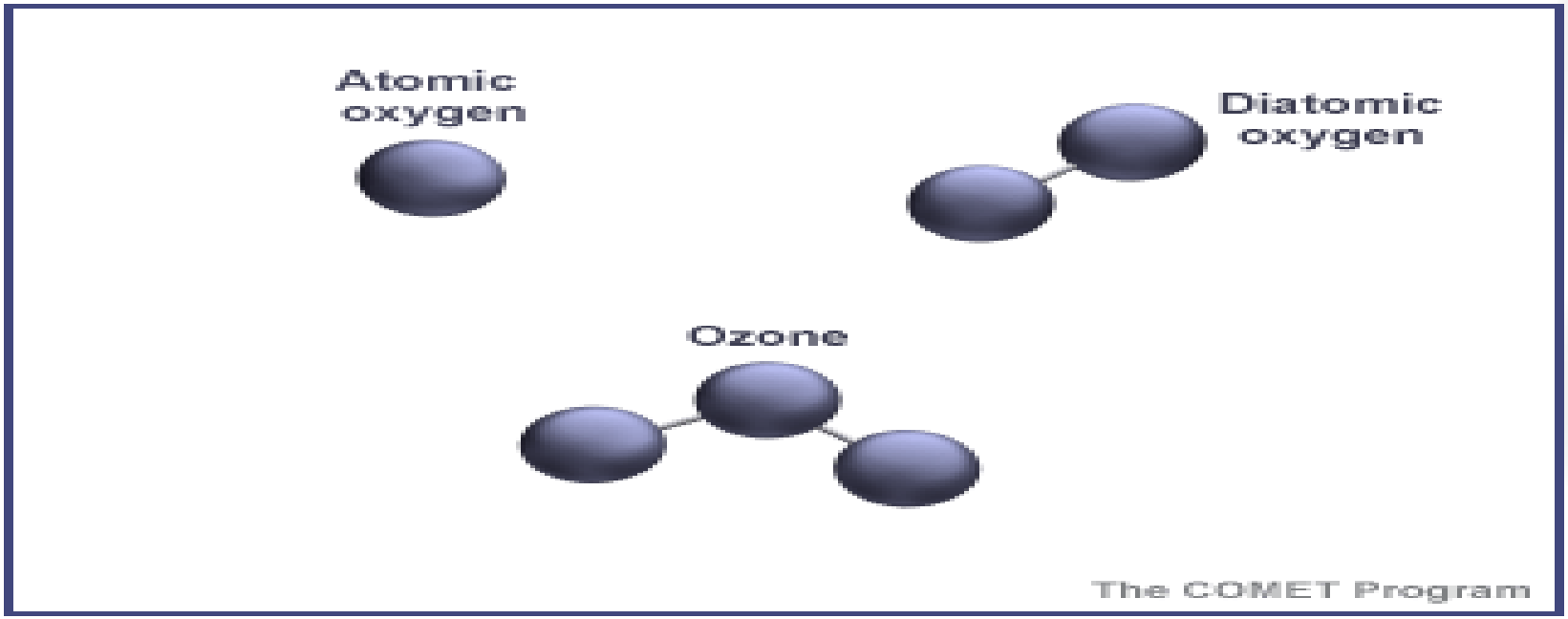
# CFC's or Chlorofluorocarbons

UV light in the atmosphere would break the bonds of the Chlorine in the CFC's and release it. Chlorine was found to deplete the ozone.

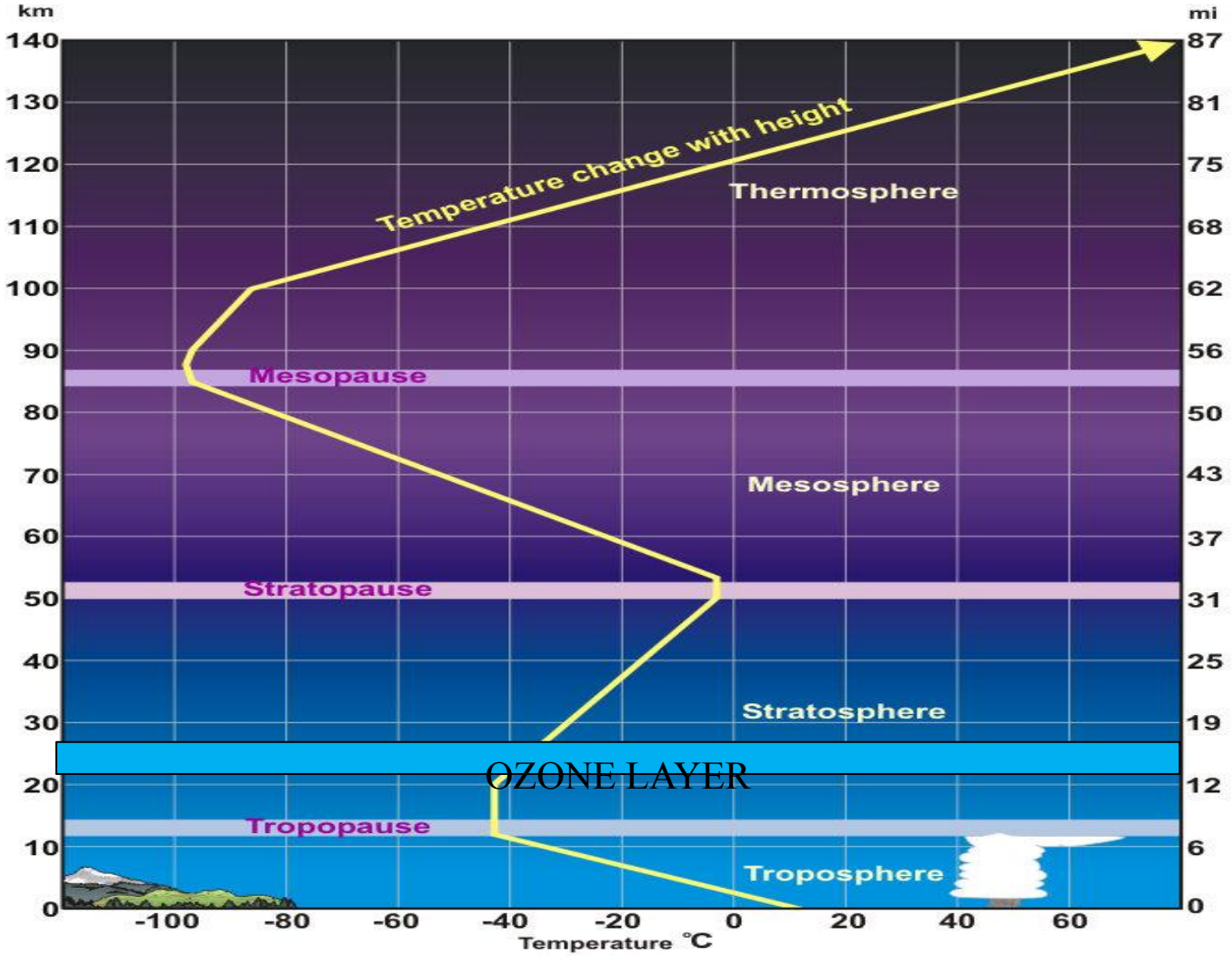
# *Ozone depletion…*

# What is ozone?

- ✓ Ozone is made of three oxygen atoms
- ✓ The oxygen we find in our atmosphere is made up of two oxygen atoms
- ✓ Because of its chemical formulation, a single atom of oxygen (O) is unstable.



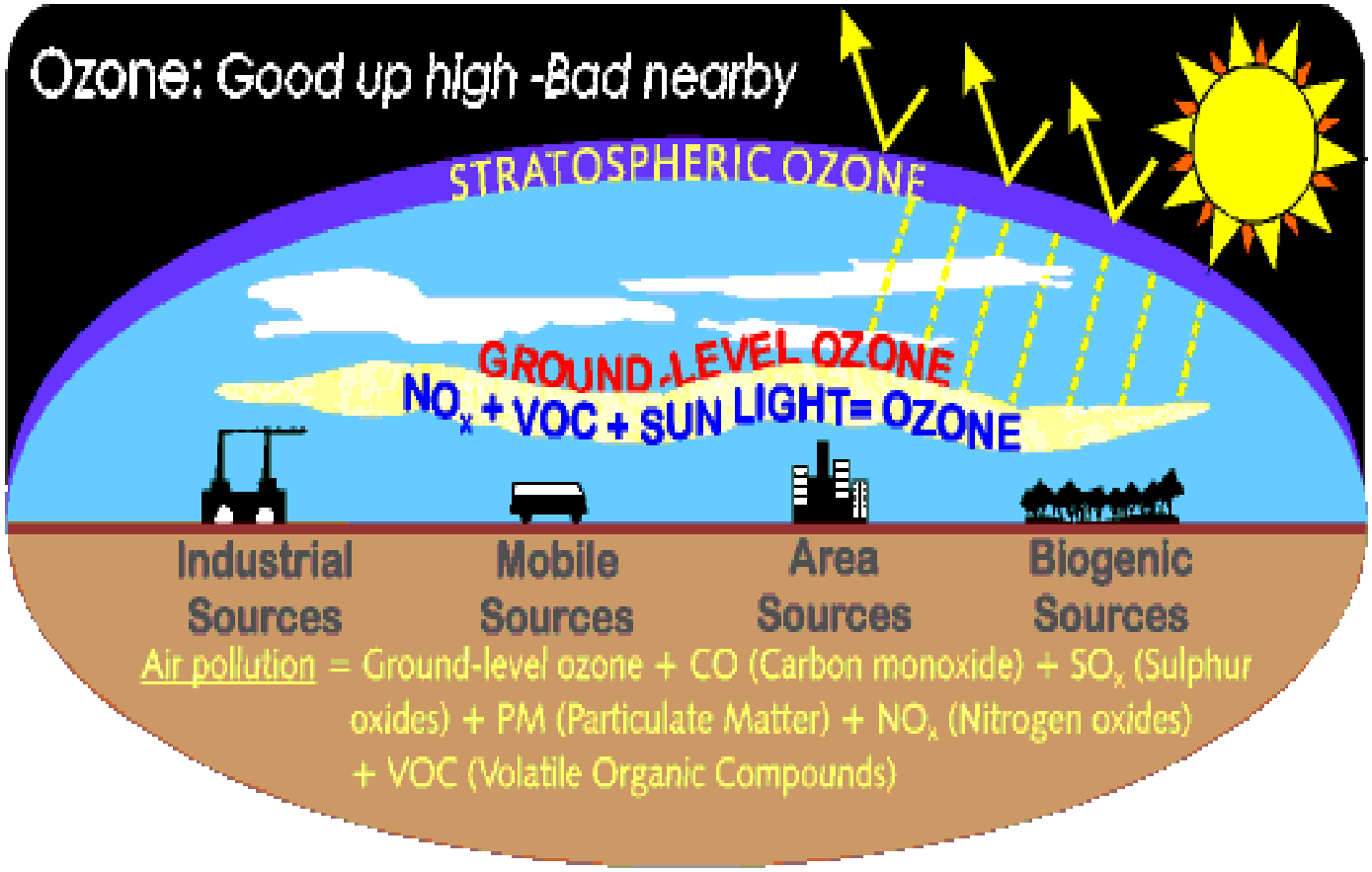
# Position of ozone



# Stratospheric and Troposphere Ozone

- ✓ **In the troposphere**, ground level ozone is a major air pollutant and primary constituent of photochemical smog.

- ✓ **In the stratosphere, the** ozone layer is an essential protector of life on earth as it absorbs harmful UV radiation before it reaches the earth.


Ozone: Good up high -Bad nearby
STRATOSPHERIC OZONE
GROUND-LEVEL OZONE
$NO_x$ + VOC + SUN LIGHT= OZONE
Industrial Sources
Mobile Sources
Area Sources
Biogenic Sources
Air pollution = Ground-level ozone + CO (Carbon monoxide) + $SO_x$ (Sulphur oxides) + PM (Particulate Matter) + $NO_x$ (Nitrogen oxides) + VOC (Volatile Organic Compounds)

# How is Stratospheric ozone formed?

- ✓ Ozone is formed naturally in the upper stratosphere by short wavelength ultraviolet radiation.
- ✓ Wavelengths less than ~240 nanometers are absorbed by oxygen molecules ($O_2$), which dissociate to give O atoms.
- ✓ The O atoms combine with other oxygen molecules to make ozone:
- ✓ $O_2$ + hv (light) -> O + O (wavelength < 240 nm)
- ✓ O + $O_2$ -> $O_3$

# How is Tropospheric ozone formed

- ✓ $N_2 + O_2 \rightarrow 2\,NO$ ( heat)
- ✓ $2\,NO + O_2 \rightarrow 2\,NO_2$
- ✓ $NO_2 \rightarrow NO + O$ (UV light)
- ✓ $O + O_2 \rightarrow O_3$

# Ozone depleting substances

- **Chlorofluorocarbons (CFCs)** – e.g. R11, R12 (phased out January 2006)

✓ R11 – refrigerant in chillers

✓ R12 - refrigerant in refrigerators, car air conditioning units propellants in aerosol cans

- **Carbon tetrachloride; methyl chloroform** (phased out 2007 with exemption)

✓ Solvents

- **Halons (bromofluorocarbons or BFCs)** (phased out 2002 with exemption)

✓ Fire extinguishers

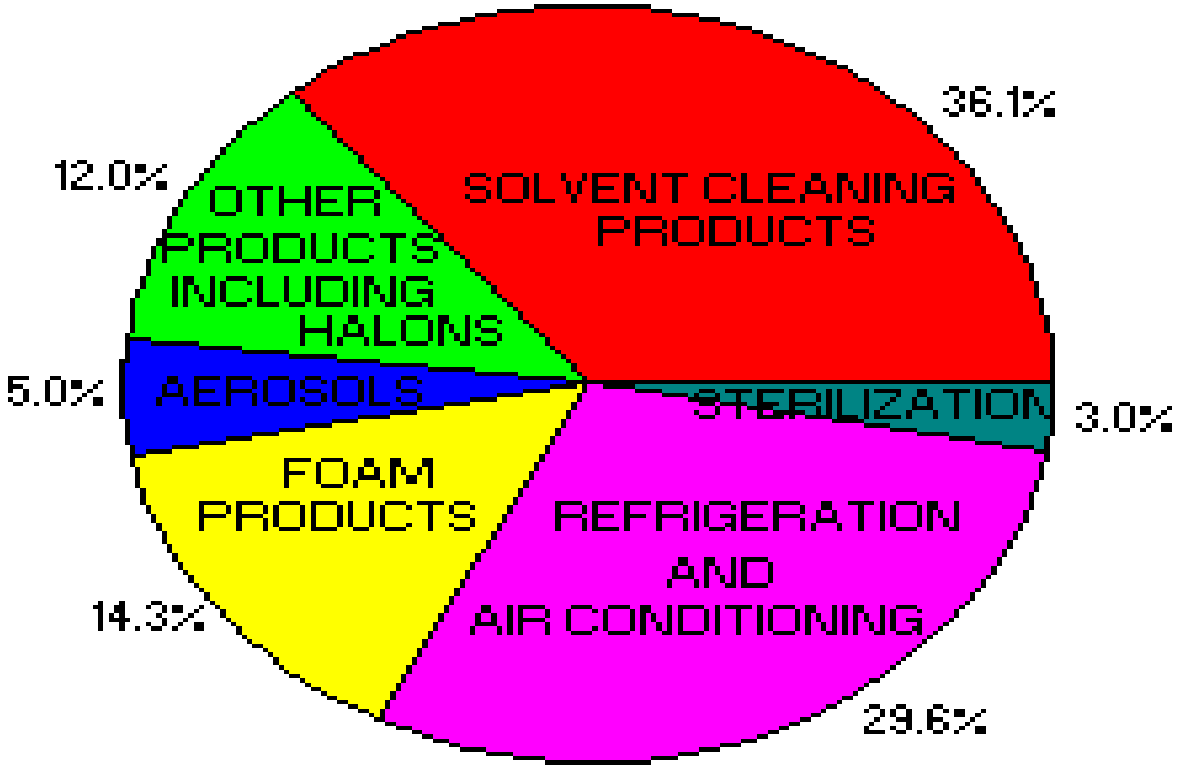
- **Methyl bromide** (to be phased out in 2009)

✓ Pesticide (fumigant)

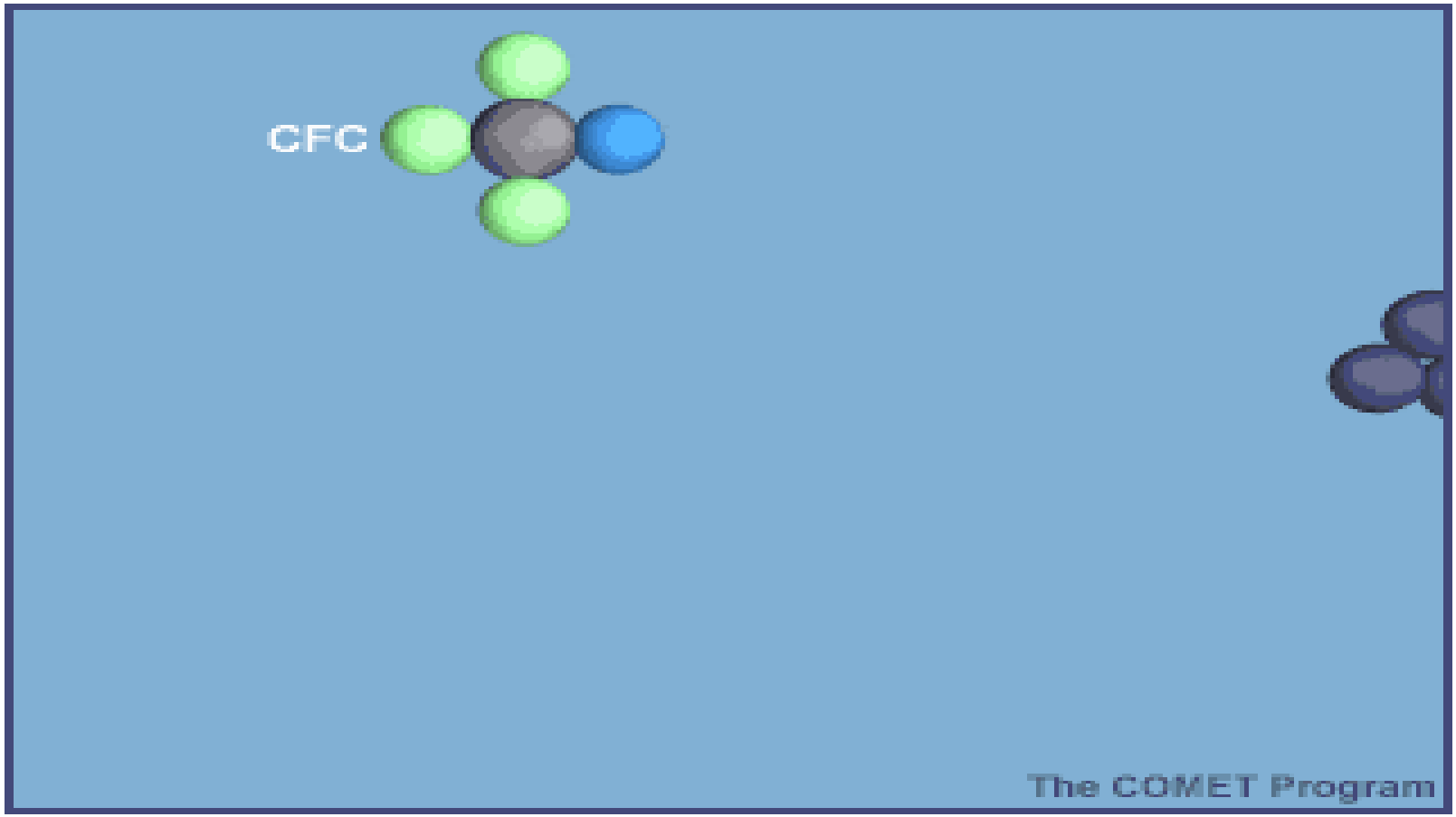
- **Hydro chlorofluorocarbons** e.g. HCFCs (freeze in 2013; phase out in 2030)

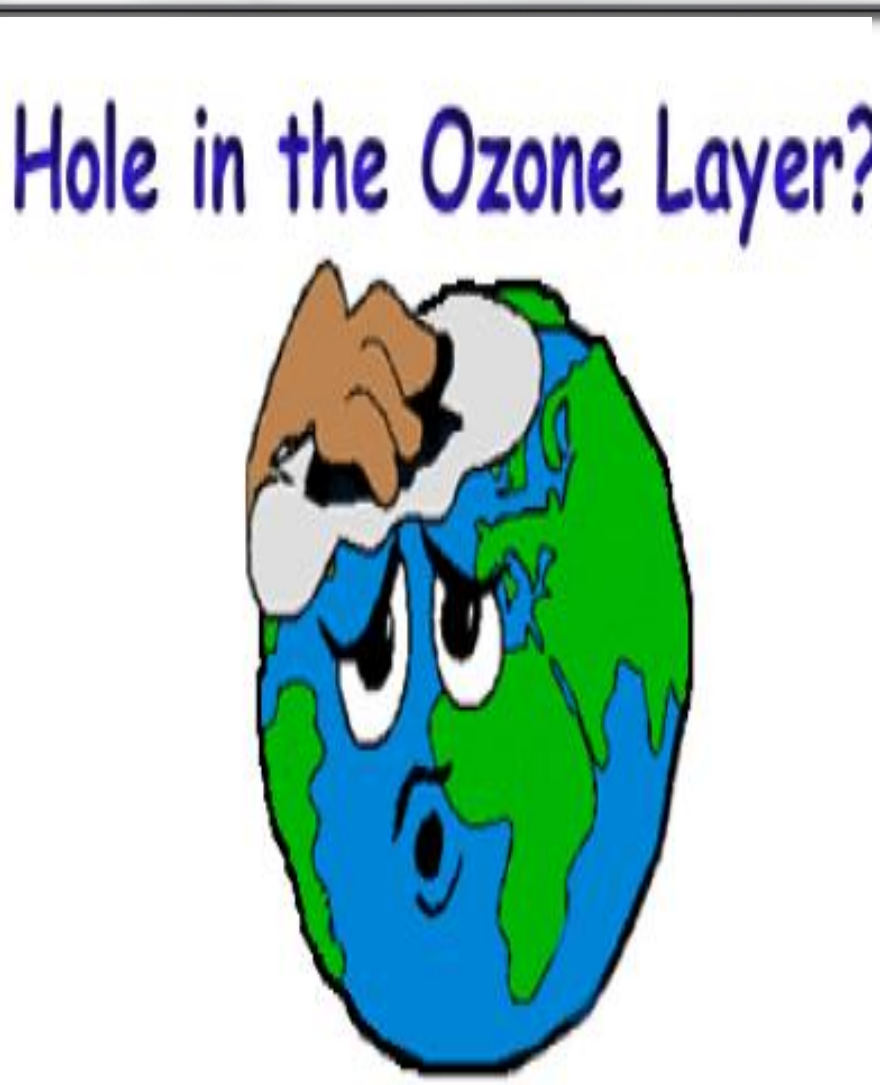
✓ Refrigerants (substitutes for CFCs)

# SOURCES OF
# OZONE DEPLETING SUBSTANCES



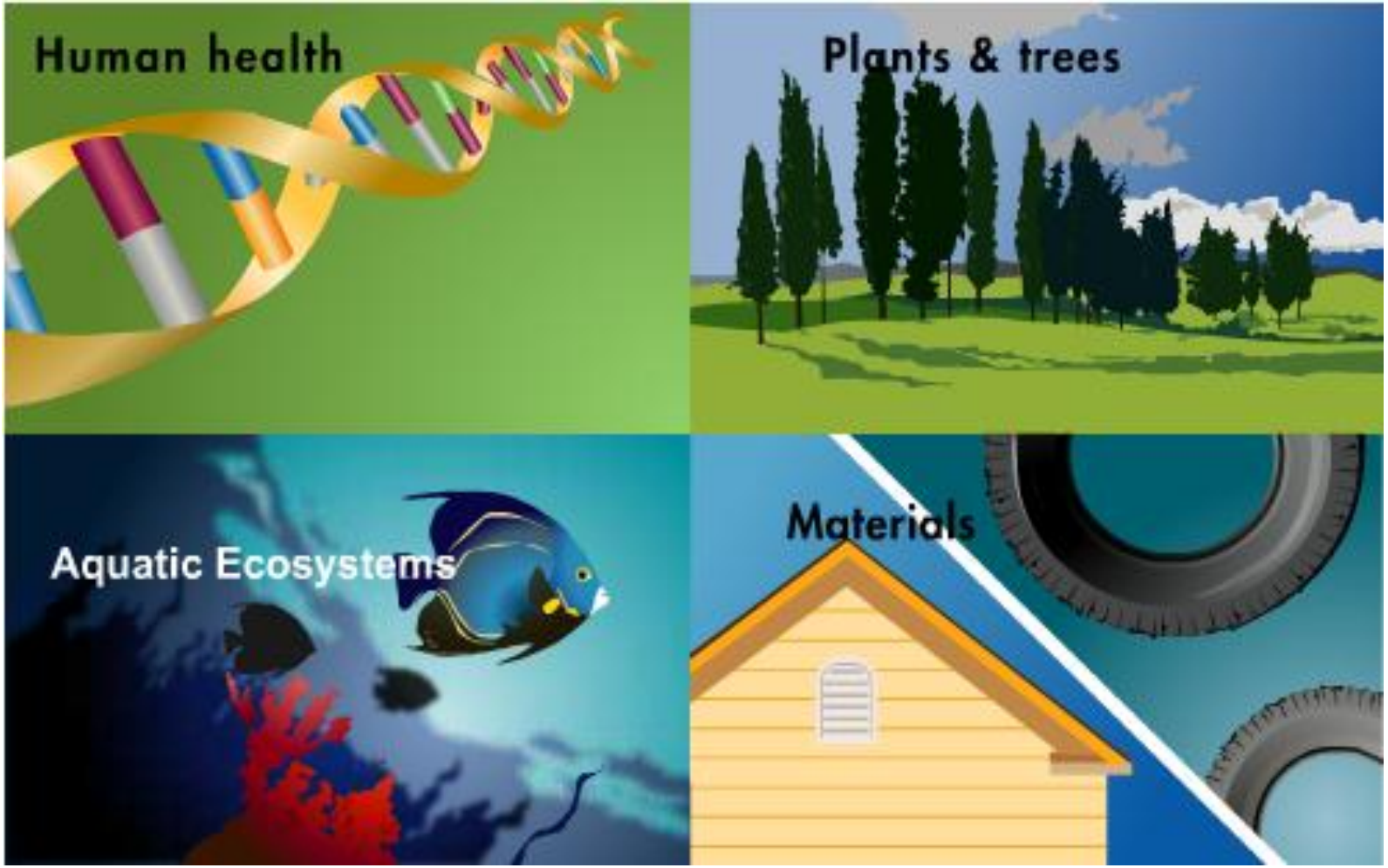
# How CFC's interact with Ozone?






- ✓ Two ingredients are extremely important: cold temperatures and sunlight.
- ✓ Cold temperatures are needed to form PSCs to provide surfaces on which heterogeneous reactions take place.
- ✓ Sunlight is required to photolyse chlorine containing species (Cl2, ClNO2, and HOCl).

# Effects of ozone depletion

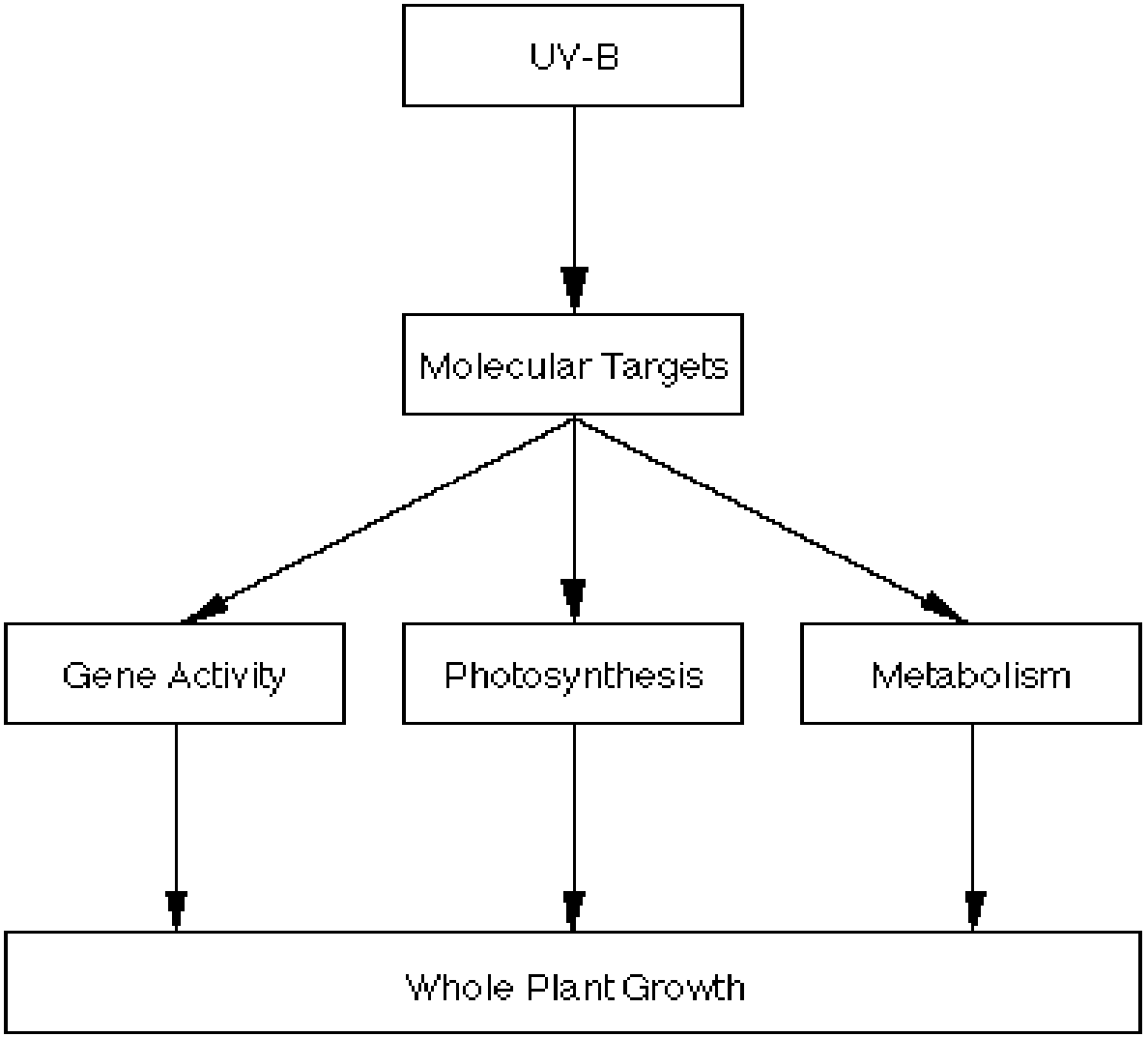


# Effects of UV radiation on biological organisms

- **DNA damage**…….. Maximum effect on small and single cell organisms
- **Impaired growth and photosynthesis** ...poor crop yields
- **Phytoplankton**: ……...Reduced uptake of $CO_2$
  ……..mortality
  ……..Impaired reproductive capacity
- **Nitrogen-fixing soil bacteria**……. Reduced, damaged
- **Human health effects**:

Suppressed immune system……..Enhanced susceptibility to infection
……..Increase risk of Cancer
Dermatology (skin)……...Sunburn
…….....Loss of skin elasticity (Premature aging)
……. Photosensitivity
Neoplasia (cancer)……....Melanocytic (malignant melanoma)
…….....Squamous cell skin – cancer
…….……Basal skin – cancer
Still questionable if causes lip cancer or cancer of the salivary glands
Oculur (Eye)…….....Cataract
…….....Pterygium

# The influence of the UV-B radiation on plant process.




*Environmental Effects of Ozone Depletion: 1994 Assessment*

# Effects on Human Health

- Over exposure may:
  - Increase risk of non-melanoma and malignant melanoma skin cancer
    - Higher risks of malignant melanoma from severe sunburns – especially in childhood
    - Risk of malignant melanoma has increased 10%
    - Risk of nonmalignant melanoma has increased 26%



# Over Exposure

- Suppress immune system
- Accelerate aging of skin due high exposure
- Cause an outbreak of rash in fair skinned people due to photo allergy – can be severe



dermis.multimedica.de/.../ en/13007/image.htm

# Alternatives of CFCs

- First generation replacement of CFCs as refrigerants : HCFCs
- Second generation replacement of CFCs as refrigerants : HFCs
- Third generation replacement of CFCs as refrigerants : ammonia vapor compression system, hydrocarbons vapor compression system
- Future replacement : $CO_2$ as refrigerant

# Global Warming Can Increase Ozone Depletion

- ✓ continued global warming will accelerate ozone destruction and increase stratospheric ozone depletion.
- ✓ Ozone depletion gets worse when the stratosphere (where the ozone layer is), becomes colder.
- ✓ Because global warming traps heat in the troposphere, less heat reaches the stratosphere which will make it colder.
- ✓ Greenhouse gases act like a blanket for the troposphere and make the stratosphere colder.
- ✓ In other words, global warming can make ozone depletion much worse right when it is supposed to begin its recovery during the next century.

# Urban Heat Island . . .

# Introduction

- ✓ An urban heat island (UHI) is a metropolitan area which is significantly warmer than its surrounding rural areas.
- ✓ Dark materials absorb solar energy and release it back t the surrounding air as heat. This condition causes the temperature in urban areas to be much hotter than rural areas.
- ✓ The temperature difference usually is larger at night than during the day, and is most apparent when winds are weak.
- ✓ Seasonally, UHI is seen during both summer and winter.
- ✓ The air in an urban heat island can be as much as 20°F (11°C) higher than rural areas surrounding the city.

# Causes:

- ✓ The main cause of the urban heat island is modification of the land surface by urban development which uses materials which effectively retain heat.

- ✓ As population centres grow they tend to modify a greater and greater area of land and have a corresponding increase in average temperature.

# Reason for night time warming

- ✓The principal reason for the night-time warming is that "buildings block surface heat from radiating into the relatively cold night sky".
- ✓Two other reasons:
- ✓thermal properties of surface materials.
- ✓ lack of evapotranspiration in urban areas.

- ✓ Other causes of a UHI are due to geometric effects.
- ✓ The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated.
- ✓ Another effect of buildings is the blocking of wind, which also inhibits cooling by convection.
- ✓ Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the UHI. High levels of pollution in urban areas can also increase the UHI.

# Social And Environmental Effects Of Urban Heat Islands

- ✓ due largely to the thermal and topographical properties of buildings that create effective heat traps for solar radiation.
- ✓ they can cost cities millions in terms of health care and energy usage.
- ✓ This results in a number of social and environmental effects, such as
- ✓ higher mortality rates,
- ✓ greater energy usage and
- ✓ potential water shortages.

- ✓ There are around 120 heat related deaths in London every year.
- ✓ In the USA as a whole, 400 people die annually from heat stress.

- ✓ In India:
- ✓ Orissa heat wave death- happened in 29th apr-20 death rate-113

# Reduced Precipitation in Urban Areas

- ✓ Because the cities are hotter than their surrounds, it will receive less precipitation than their surrounds.
- ✓ This can also have a knock on effect for
- ✓ water usage and the combination of high demand,
- ✓ increased temperatures and
- ✓ reduced rainfall can make urban areas the focus of summer droughts.

# Environmental effects of impervious surfaces:

- ✓Impervious surfaces  can modifies urban air and water resources
- ✓The pavement materials seal the soil surface, eliminating rainwater infiltration and natural groundwater recharge.
- ✓"Impervious surfaces collect solar heat in their dense mass. When the heat is released, it raises air temperatures, producing “urban heat islands“

- ✓ “increasing energy consumption in buildings”.

- ✓ The warm runoff from impervious surfaces reduces dissolved oxygen in stream water
- ✓ making aquatic life still harder.
- ✓ Impervious pavements deprive tree roots of aeration, eliminating the "urban forest".
- ✓ Because impervious surfaces displace living vegetation, they reduce
- ✓ ecological productivity, and
- ✓ interrupt atmospheric carbon cycling.

# Impacts on air and water:

## Air:

Increased temperatures and sunny days help lead to the formation of low-level ozone from volatile organic compounds and nitrous oxides which already exist in the air.

As urban heat islands lead to increased temperatures within cities, they contribute to worsened air quality.

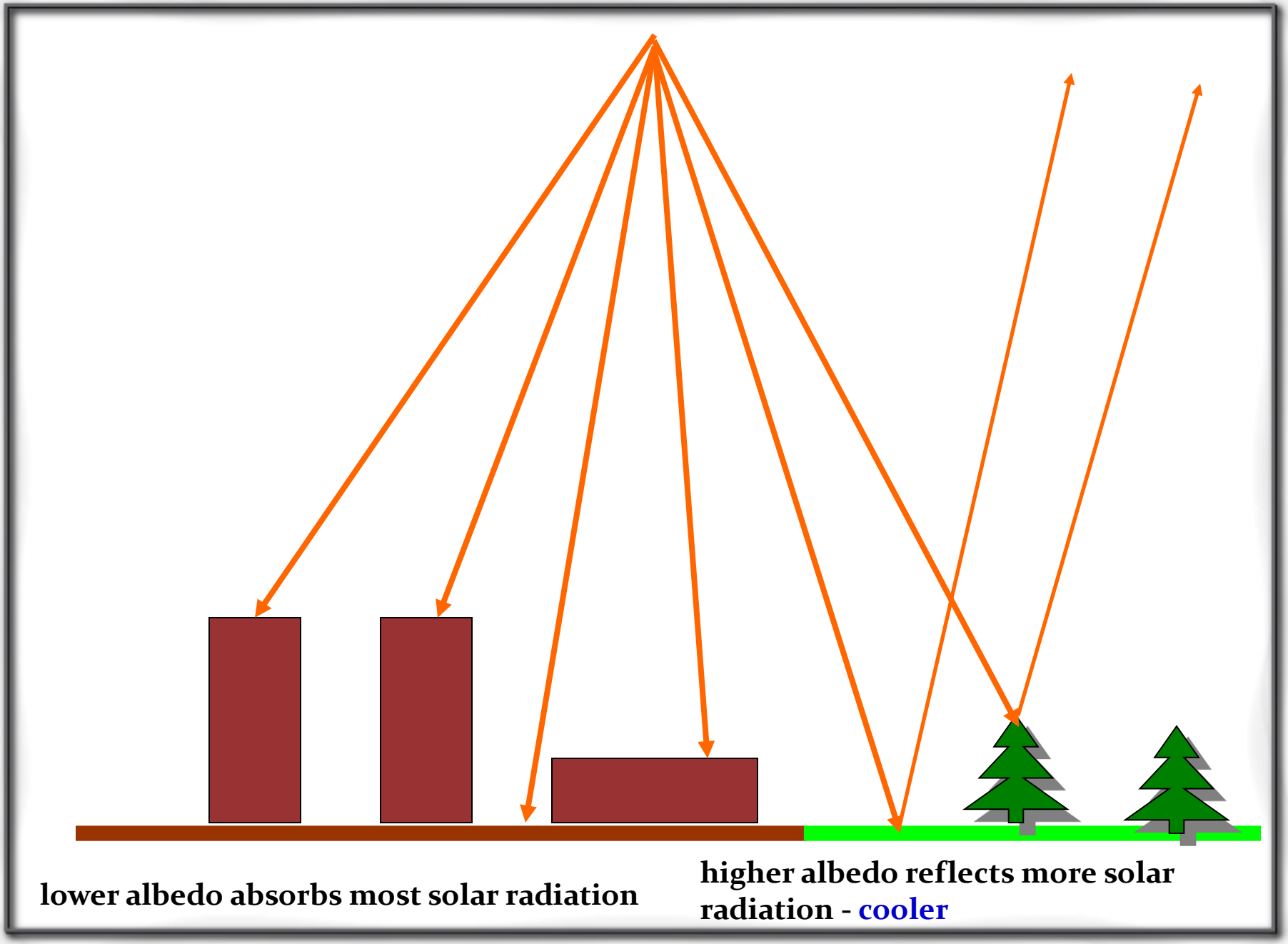
## Water:

Hot pavement and rooftop surfaces transfer their excess heat to storm water, which then drains into storm sewers and raises water temperatures as it is released into streams, rivers, ponds, and lakes.

Rapid temperature changes can be stressful to aquatic ecosystems

## The Effect of building materials on Albedo

- ✓ Building materials generally have a lower albedo than soil and vegetation.
- ✓ The result is that buildings, streets, parking lots, etc. absorb more solar radiation than soil and vegetation.
- ✓ The increased absorption of solar radiation makes the city warmer than the surrounding rural area on sunny days.


lower albedo absorbs most solar radiation
higher albedo reflects more solar radiation - cooler

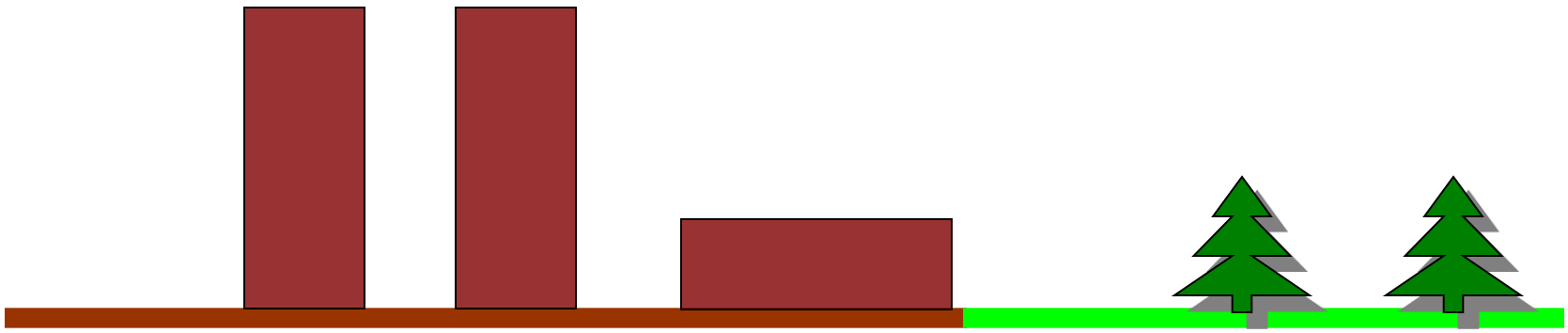
# The Effect of Building Materials on Storage of Internal Energy

- ✓ Building materials generally have higher heat capacities than soil and Vegetation.

- ✓ This means that buildings, streets and parking lots tend to retain internal energy longer and stay warmer than surrounding rural areas especially at night.

**building materials have higher heat capacities and store more internal energy**

Vegetation has lower heat capacity and can't store much internal energy



**temperature inside a city stays higher at night**

**temperature decreases more quickly in rural areas cooler at night**

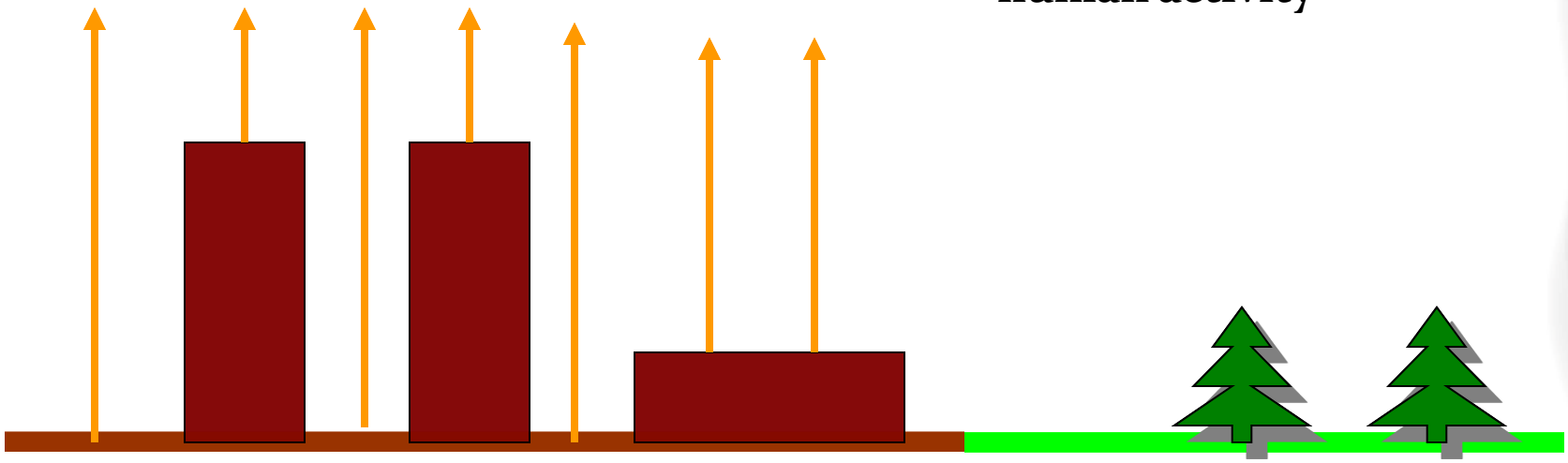
# Generation of Internal Energy By Human Activity

- ✓ Many human activities generate internal energy as a waste byproduct (e.g. power plants, industrial processes, energy loss from buildings).

- ✓ The much higher population densities in cities mean that these processes generate much more energy than in surrounding rural areas.

Internal energy generated as a result of human activity

very little internal energy generated as a result of human activity



higher temperatures

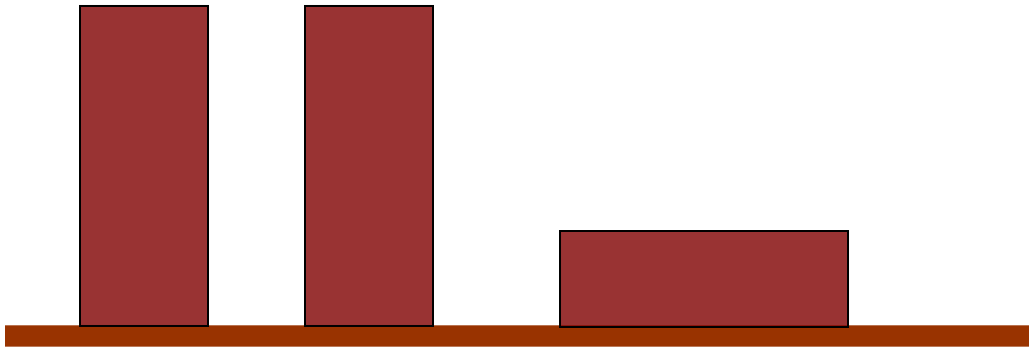
lower temperatures

# Reduced Evaporation (Cont.)

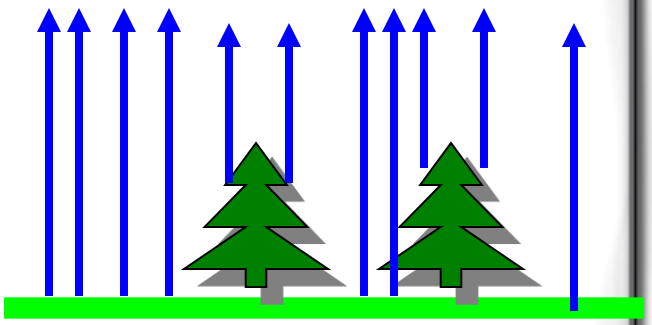
- ✓The reduced evaporation in the city means that the relative humidity is lower than it is in surrounding rural areas.

- ✓Since water absorbs energy when it evaporates, the reduced evaporation in the city also contributes to higher temperatures than in the surrounding rural areas.

much less evaporation occurs over a city



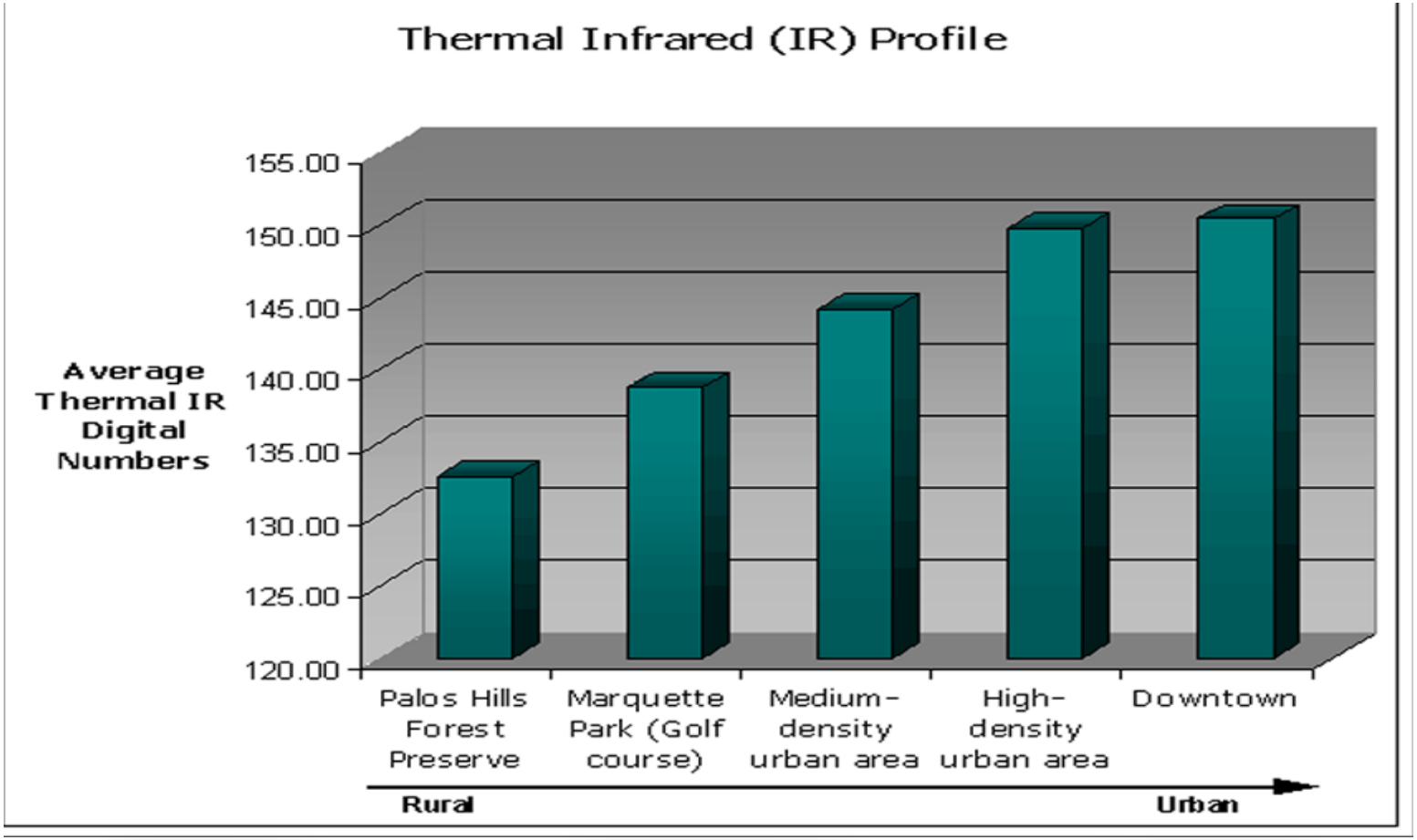
much more water evaporates in the surrounding rural areas



the relative humidity tends to be lower over a city and the temperature higher

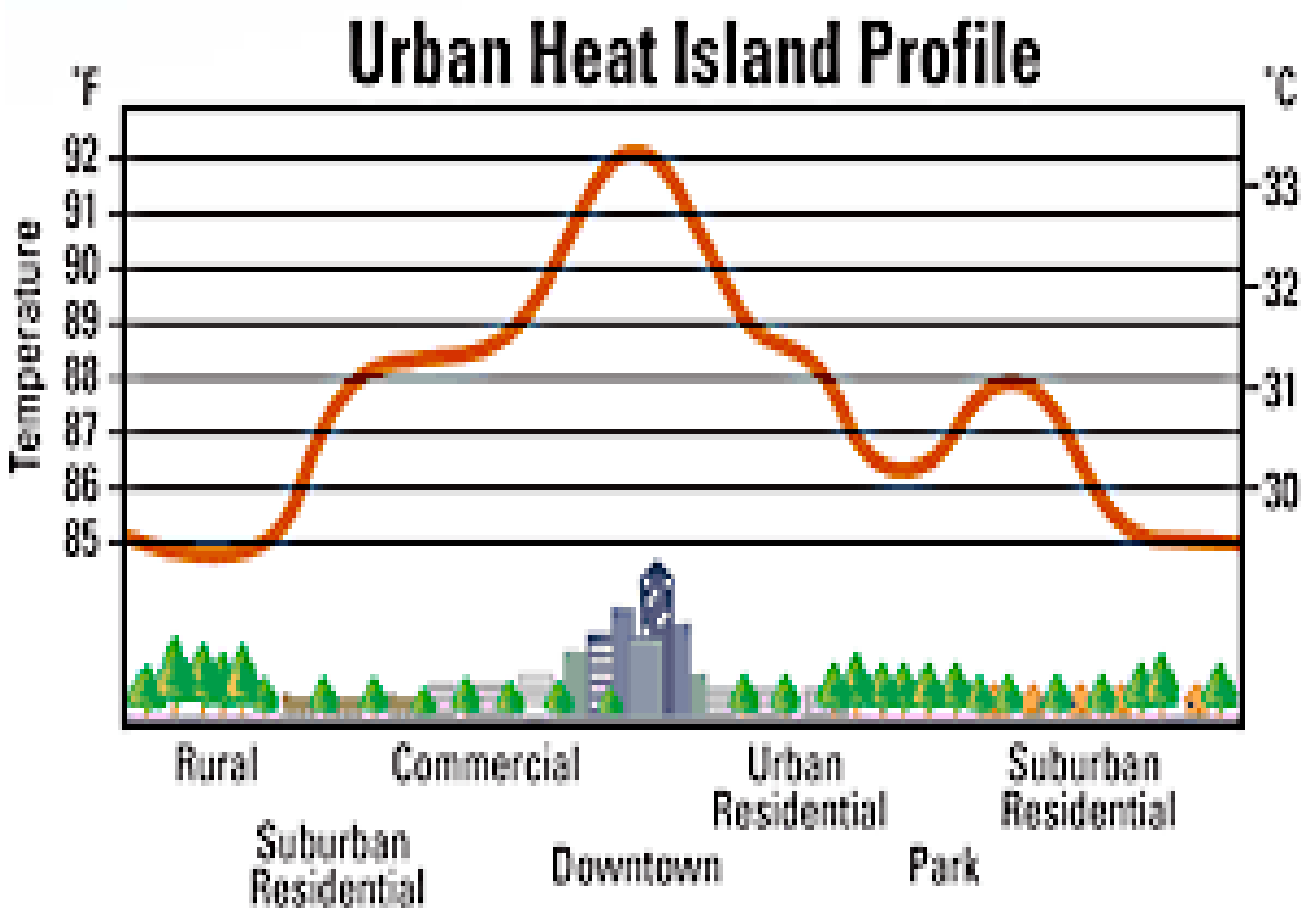
the relative humidity is higher and the temperature is lower

# Relationship between land cover and thermal conditions



# Heat Islands Contribute to Global Warming

- ✓ During the summer months they can contribute to global warming.
- ✓ The increased use of air conditioning and refrigeration needed to cool indoor spaces in a heat-island city, for example, results in the release of more of the heat-trapping greenhouse gases that cause global warming


Urban Heat Island Profile
°F
°C
Temperature
92
91
90
89
88
87
86
85
33
32
31
30
Rural
Suburban Residential
Commercial
Downtown
Urban Residential
Park
Suburban Residential

# Urban Heat Island Mitigation

action to reduce urban heat islands using four main strategies:

1) increasing tree and vegetative cover,
2) installing green roofs (rooftop gardens or eco-roofs),
3) installing cool—mainly reflective—roofs, and
4) using cool pavements.

# Trees and Vegetation

- ✓ Trees and other plants help cool the environment, making vegetation a simple and effective way to reduce urban heat islands.

Shading in parking lot medians can provide extensive shading coverage

- ✓Trees  not only helps to reduce the urban heat island effect, but also it reduces
- ✓air pollution.
- ✓higher demands on cooling systems  and
- ✓health problems related to heat and pollution.

- ✓Trees are a very simple, attainable means of reducing the effects.
- ✓They act as nature's air conditioners.
- ✓Leaves help reduce air pollution by "capturing" airborne particles, such as
- ✓Nitrogen dioxide, $NO_2$,
- ✓Nitrogen oxide, NO, and
- ✓Sulfur dioxide, $SO_2$

# Green Roofs

Green roofs provide shade and remove heat from the air through Evapotranspiration, reducing temperatures of the roof surface and the surrounding air. On hot summer days, the surface temperature of a green roof can be cooler than the air temperature

This apartment building in Portland, Oregon, is among the 6 acres (24,300 m2) of green roofs in the city, as of 2007

# Cool Roofs

- ✓ A high solar reflectance or albedo is the most important characteristic of a cool roof as it helps to reflect sunlight and heat away from a building, reducing roof temperatures.

- ✓ High thermal emittance help roofs to absorb less heat and stay up to 50–60°F (28–33°C) cooler than conventional materials during peak summer weather.

# Benefits of Mitigation

- ✓ can reduce heating and cooling energy use.
- ✓ air pollution and greenhouse gas emissions, remove air pollutants.
- ✓ lower the risk of heat-related illnesses and deaths.
- ✓ improve storm water control and water quality
- ✓ increase property values.
- ✓ enhance night-time illumination.
- ✓ reduce noise levels, create habitats, improve aesthetic qualities.

# Dust Storms...

# Dust Storms

- ✓ Composed of tiny particles that are lifted high into the atmosphere
- ✓ So dense it obscures the sun and can reduce visibility to zero across areas as large as hundreds of thousands of square miles
- ✓ Primarily affect arid and semiarid regions
- ✓ They generally do not occur in the driest areas due to the ground being hard and flat with rocks and gravel rather than sand

# Dust Storms (continued)

- ✓ Dust storms occur during times of drought when the soil is loose due to lack of moisture
- ✓ The most prone areas of the world are north Africa, the Middle East, the southern United States (Texas, California, Arizona), and Central Asia
- ✓ Material can be carried thousands of miles
  - Dust from Sahara settles as far away as Florida

# Dust Storms (continued)

- ✓ Dust from Texas has been identified through chemical analysis in every eastern state as well as parts of Europe

- ✓ Every four seconds, a boxcar of sand leaves the Sahara

# Haboob

- ✓ A tumbling black wall of sand stirred up by cold downdrafts along the leading edge of a thunderstorm or cold front.
- ✓ Caused by downdrafts on the leading edge of a thunderstorm.
- ✓ Frequent in deserts of the Sudan and north-central Africa as well as the south-western United States.

# Haboob (continued)

- ✓ Most dust storms are classified as haboobs
- ✓ They last 30 minutes to an hour
- ✓ They can travel around 48 km/h
- ✓ Dust caught in the haboob can be thrown up to 23000 feet into the air

# Cause: Harmattan

- ✓ A mild, dry and dusty wind originating in the Sahara desert
- ✓ Main cause of sand storms in west Africa
- ✓ 2-3 times every year, reddish Saharan dust makes its way to Great Britain
  - Here, it falls as a red precipitation that the locals call "blood rain"
- ✓ Resulting dust storms can be 20000 feet high

# Simoom

- ✓ Hot, dry, blustery, dust-laden wind that blows across the Sahara and the deserts of Israel, Syria, and the Arabian Peninsula

- ✓ Often reaches temperatures of more than 54°C and has been known to cause heat stroke, earning it the nickname "poison wind"

# Shamal

- ✓ Hot, dry, dusty wind producing storms throughout the Persian Gulf
- ✓ Occurs various times in the year for one to five days at a time
- ✓ Once a year in June and early July it blows for a straight forty days at roughly 50 km/h
  - This is known as the Great Shamal

# Khamsin

- ✓ Hot, dry, southerly wind that originates on the Sahara and produces large sand and dust storms
- ✓ Forms over Libya and Egypt
- ✓ Its name is Arabic for "fifty" because it lasts roughly fifty straight days, starting in the middle of March

# Effects: On Agriculture

- ✓ Strips the land of the most fertile soil
- ✓ Increases food prices
- ✓ Kills seedlings or stunts growth
- ✓ Can introduce pathogens that cause plant disease

# Effects: On Health

- ✓ Inhalation of airborne dust and sand can cause damage to lungs and sinuses, and can trigger allergy attacks
- ✓ During and after sand storms, hospitals and clinics report increased admittances for respiratory infection, cardiac disease, bronchitis, asthma and pneumonia

# Effects: On Vehicles

- ✓ Reduced visibility causes danger for vehicles on the ground, in the air, and on the water
- ✓ Dust enters and damages motors and other machinery

# Effects: Other

- ✓ Causes millions of dollars of damage to crops, buildings, and roads
- ✓ Dirt particles rubbing together causing static electricity
  - Scrambles radio broadcasts and starts fires
  - Fire is an even greater possibility due to the low humidity

# Examples of Large Storms

- ✓ July 10, 1997 - a dust storm in south Arizona reduced visibility to zero. There were eleven accidents involving twenty eight vehicles on Interstate 10.

- ✓ August 15, 1997 – Denver, Colorado, a dust storm causes chain reaction crashes on Interstate 70. Eleven vehicles were involved in accidents and ten people were hospitalized.

# Examples of Large Storms

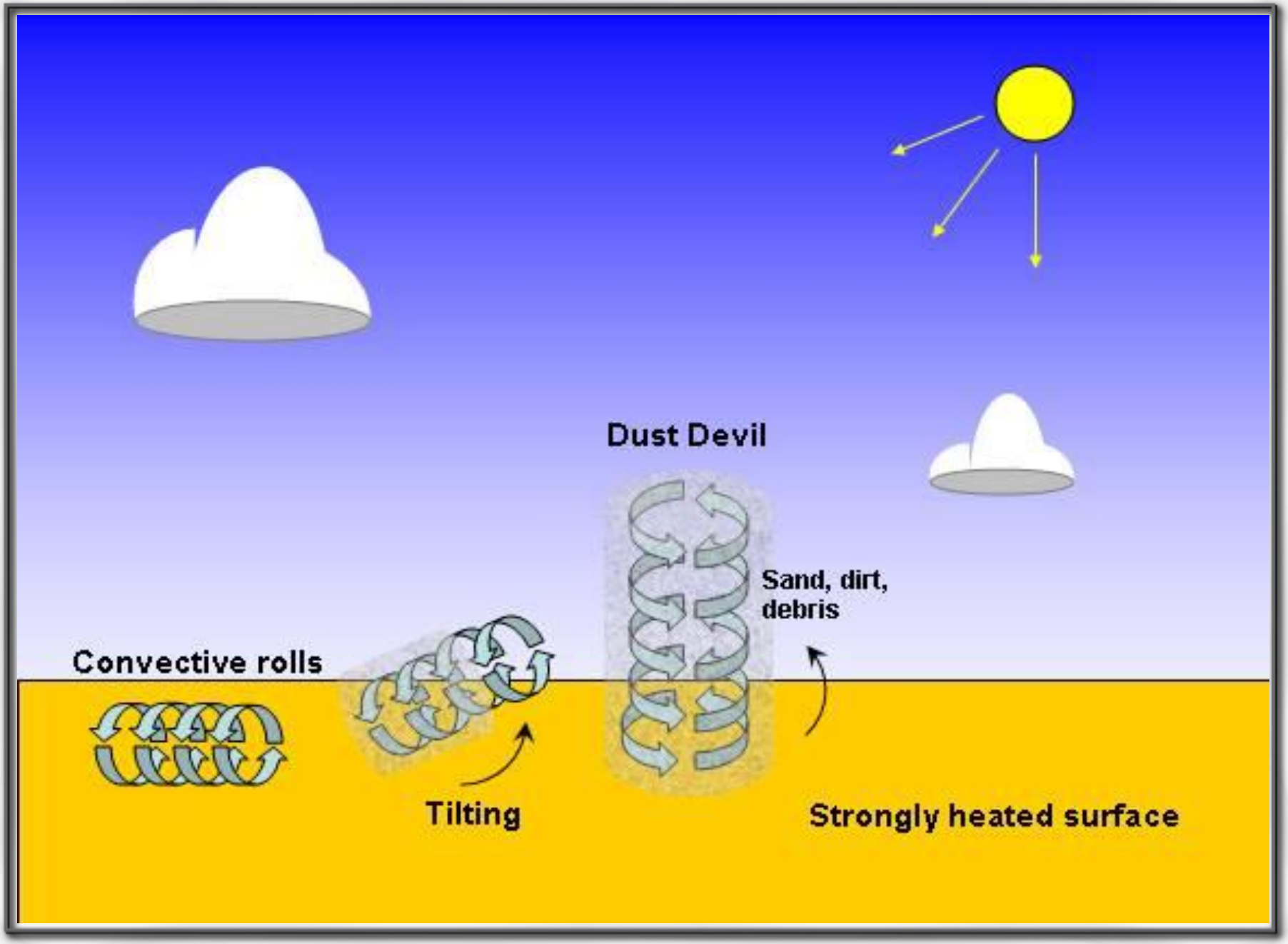
- ✓ On September 25, 1999 a dust storm moving 80 km/h developed in northern Oregon. On Interstate 84, traffic accidents were responsible for seven deaths and twenty seven injuries. Dozens of vehicles were involved in five separate pile-ups.

# If You Get Caught in a Dust Storm

- ✓ Get indoors and block all openings with wet towels
- ✓ If you are stuck outside, turn away from the wind and cover your mouth, nose, and eyes with a cloth
- ✓ If in a car, pull as far off the road as possible to avoid a collision. If on the highway shoulder, turn your lights off so other drivers do not think you are on the road and drive up behind you. Stay in the car.

# Dust Devils

- ✓ Spinning vortex of sand which is usually harmless, but may grow quite large
- ✓ A hot layer of air against the hot ground "bubbles" up into cooler air and starts spinning
- ✓ Dust devils can form as an updraft under sunny, dry conditions during fair weather
- ✓ Cold air falls in a circular pattern around a warmer core, which starts and maintains a spinning motion


Dust Devil
Sand, dirt,
debris
Convective rolls
Tilting
Strongly heated surface

# Automobile pollution sources and control…

# What is Combustion?

- ✓ Combustion occurs when a fuel reacts with oxygen to give off heat and light.
  - *Air provides enough oxygen (~20% oxygen, ~80% nitrogen)


- ✓ Fuels are typically made of carbon and hydrogen (hydrocarbons)

**What are some common fuels?**

# Why Do We Care?

- ✓ Burning of fuel is the energy source for almost all types of automobiles
- ✓ Combustion accounts for 85% of all worldwide electricity production


Source:
http://www.sunocoinc.com/market/marketplace.htm

Source:
http://museum.nist.gov/exhibits/timeline/item.cfm?itemId=27

# BUT,

- ✓ Combustion accounts for 90% of all airborne pollution

- ✓ Air pollution can lead to lung problems and shorter life spans

Link to "Lung Attack" activity

# Combustion

- ✓ Ideal combustion produces only carbon dioxide, water, and ENERGY:
  - Natural Gas:

    $CH_4 + 2\ O_2 \rightarrow CO_2 + H_2O$

  - Gasoline (approximate):

    $C_8H_{16} + 12\ O_2 \rightarrow 8\ CO_2 + 8\ H_2O$

  - Glucose in your blood/muscles:

    $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$

# Real Combustion

- ✓ Fuel does not exist as a pure substance
  - varying hydrocarbon chains

    * Jet and diesel fuel contain hydrocarbon chains of 12 to 20 carbons in length. Fuel oil contains hydrocarbons 20 to 40 carbons long.
  - sulfur (S)
  - nitrogen (N)
  - oxygen (O)
- ✓ The combustion process is NEVER complete and NEVER ideal. You will always get more than just $CO_2$ and $H_2O$

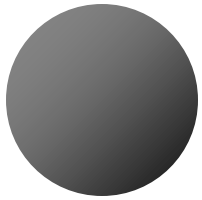
# Emissions: Automobiles

• Let's look at what happens in ideal and real combustion in automobiles. The symbols we will use are shown below:

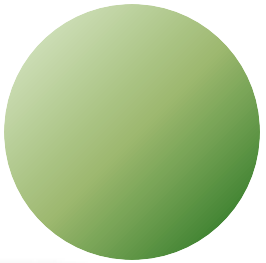
- Hydrogen (H)

- Nitrogen (N)

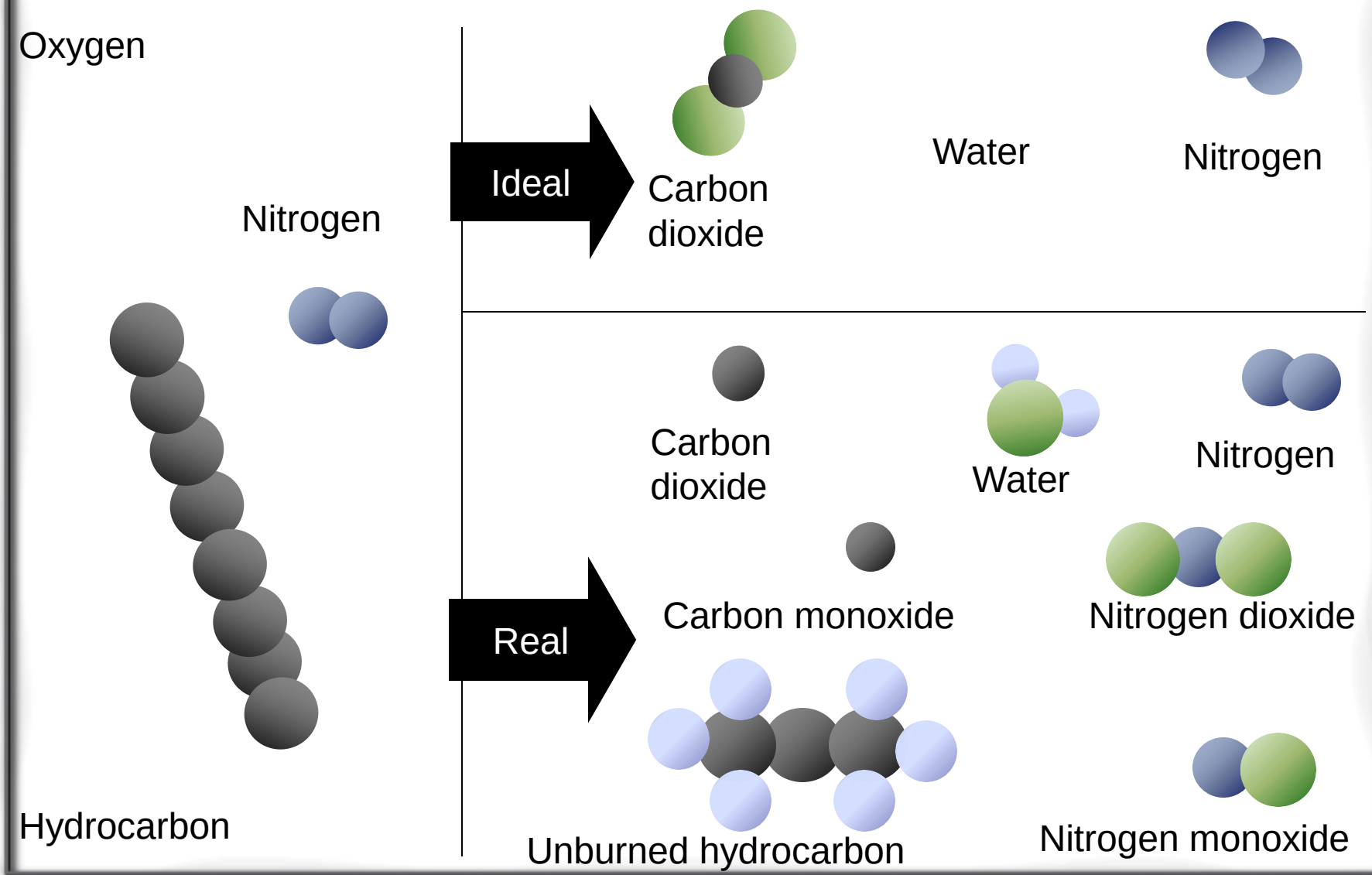
- Carbon (C)



- Oxygen (O)



# Ideal vs. Real Combustion



# Primary Emissions from Automobiles

- ✓ Carbon monoxide (CO)
- ✓ Oxides of nitrogen (NO, $NO_2$)
- ✓ Carbon as soot or particulates
- ✓ Unburned fuel (hydrocarbons)
- ✓ Carbon dioxide ($CO_2$)
- ✓ Water ($H_2O$)

# Carbon Monoxide

- ✓ Carbon monoxide (CO) – a non-irritating (won't make you cough), colorless, tasteless, and odorless gas.

- ✓ Source: rich combustion - too little air or too much gasoline

*Other sources: cigarette smoke or faulty household furnaces*

# Carbon Monoxide

- ✓ CO is POISIONOUS because it reduces the ability of blood to bring oxygen to the body's cells and tissues.

- ✓ Remember that oxygen is needed for the combustion that gives our bodies energy.

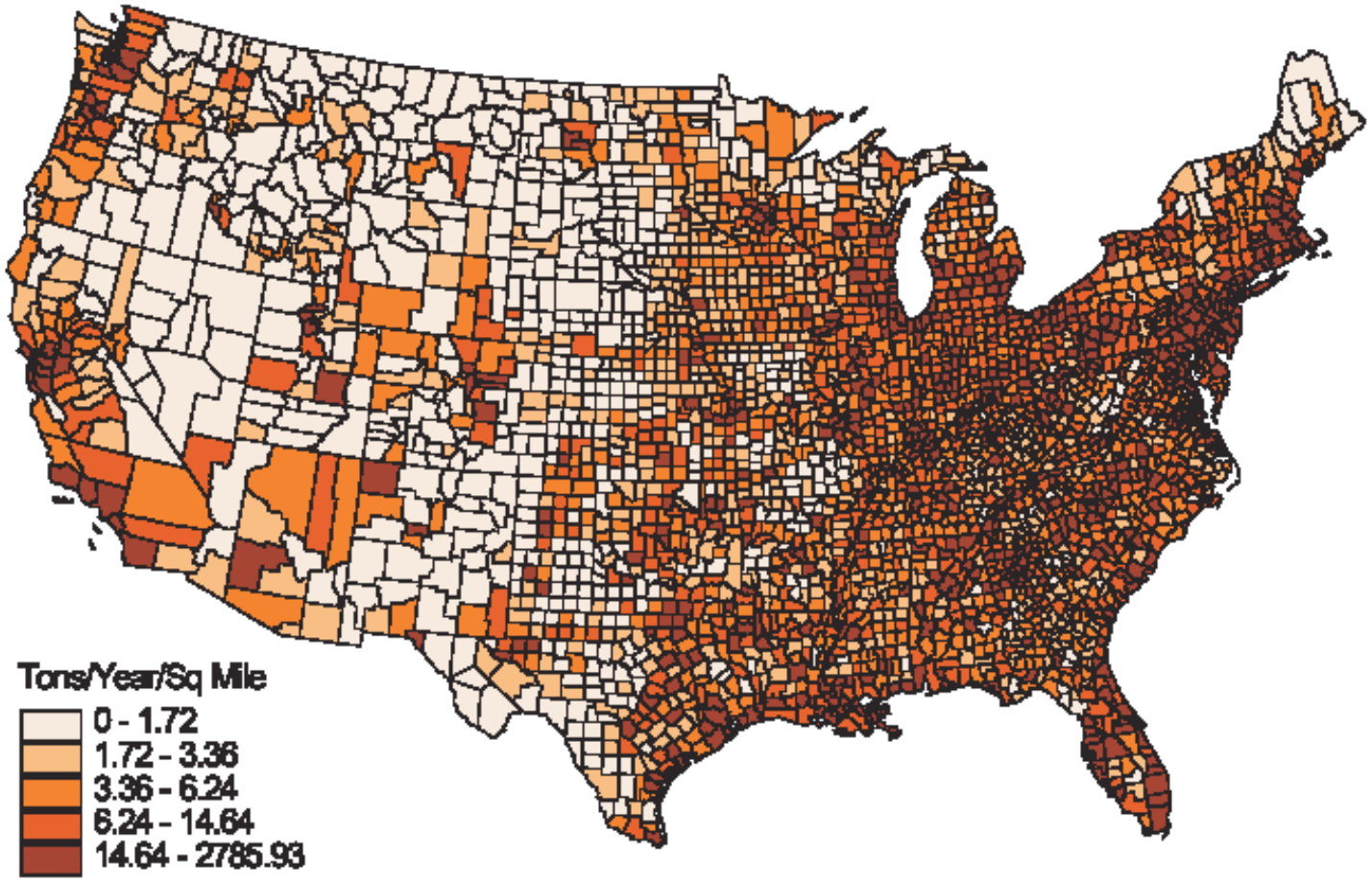
# Nitrogen Oxide

- ✓ Nitrogen oxide ($NO_x$: mainly NO, $NO_2$)
- ✓ Source: lean combustion - too little gasoline or too much air

# Nitrogen Oxide

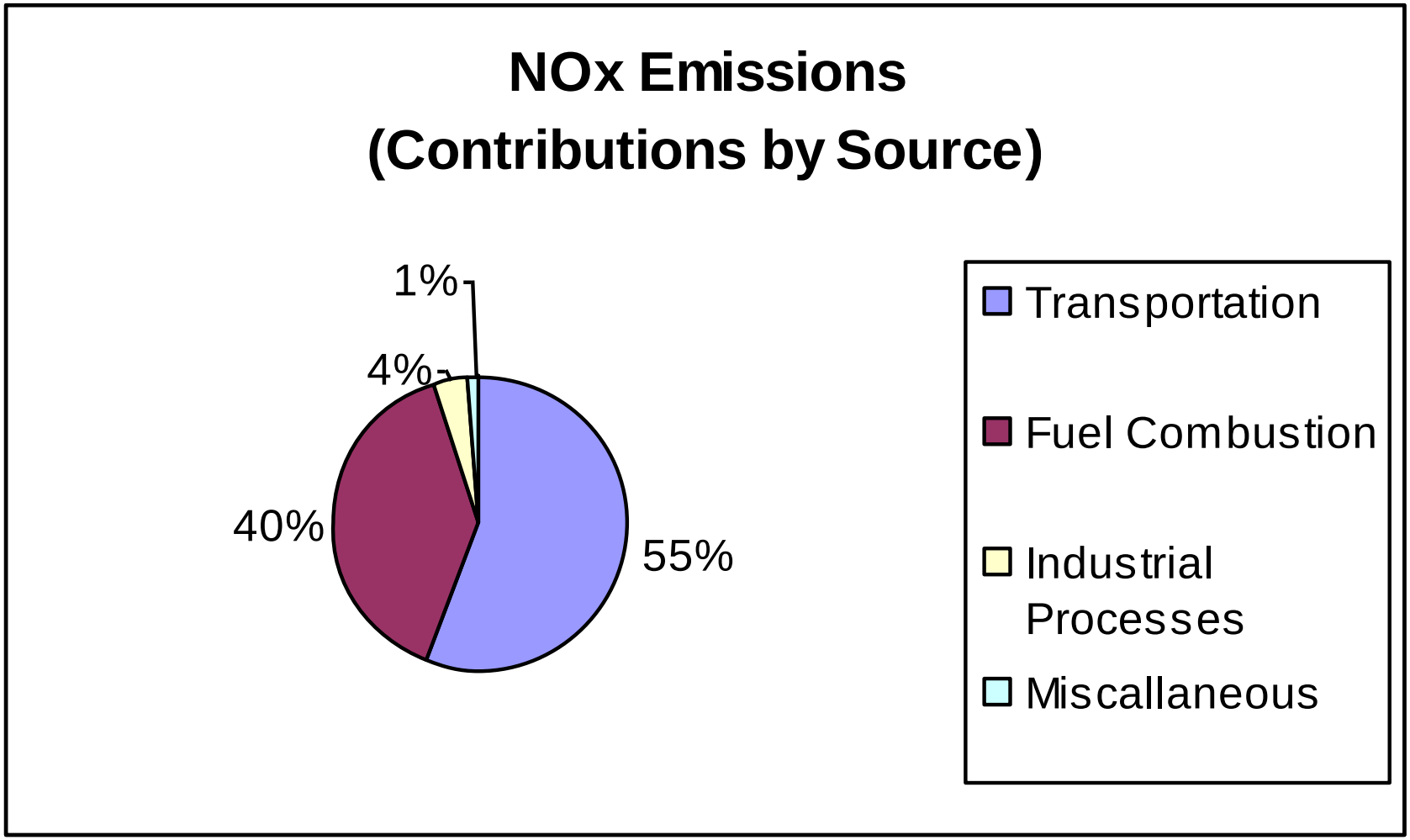
- Environmental Effects:
  - $NO_2$ is an component of acid rain
    - can damage trees and lakes
  - $NO_X$ reacts with other chemicals in sunlight to produce ozone → smog (brownish haze)
- Health Effects:
  - Lung damage
  - Illnesses such as asthma, bronchitis, and emphysema
    - (sicknesses caused by problems with breathing passages and lungs)

# $NO_x$ Emissions in the U.S.




Density map of 1999 $NO_x$ emissions.

# $NO_x$ Emissions




*NOx emissions by source, 1999*

# Particulate Matter (PM)

- ✓ Particulate Matter (PM) - small solids and liquids suspended in the air.
  - ✓ ex: Dust, Smoke, Soot

- ✓ Source: burning of wood, diesel and other fuels by vehicles, power plants, and also agriculture.

# Particulate Matter

– Health effects:

✓Nose and throat irritation

✓lung damage, bronchitis

✓early death

– Environmental effects:

✓main source of haze that reduces visibility, discolors clothes and furniture.

# Secondary Pollutants

- ✓ When emissions react with other chemicals in the atmosphere, they make secondary pollutants.

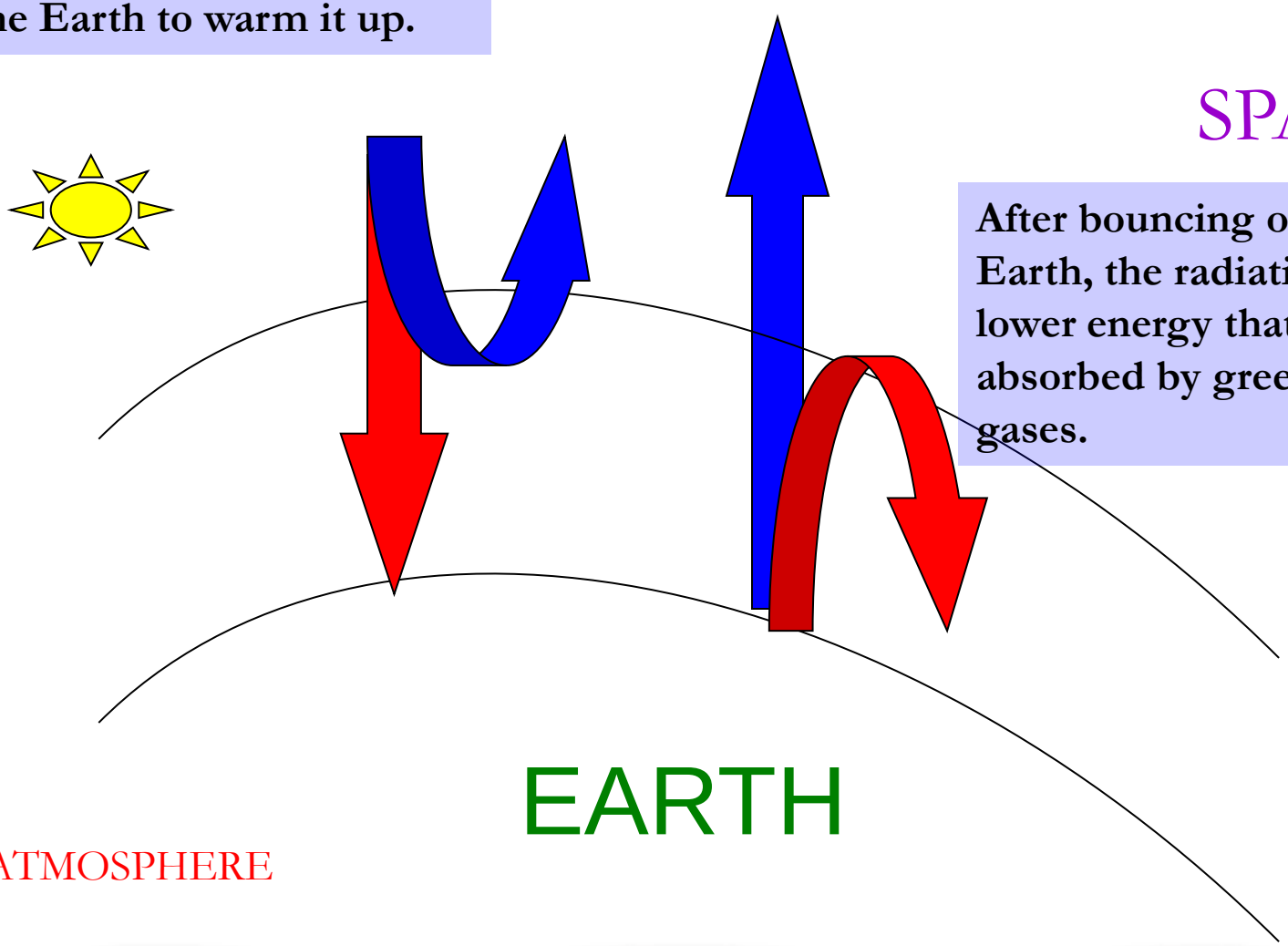
# Greenhouse Gases

- ✓ Green house gases
  - Gases that trap heat like a blanket surrounding the Earth.
- ✓ A normal concentration of these gases keep our planet at a steady temperature, but the temperature can rise if we have too many in the atmosphere.

- ✓ Greenhouse gases:
  - Carbon dioxide ($CO_2$): normal combustion
  - Methane: coal production, landfills, livestock
  - Water: airplanes and from surface water that evaporates as the Earth becomes warmer!!!

Some of the sun's radiation passes through the atmosphere and hits the Earth to warm it up.

Some of the sun's radiation is reflected back into space by the atmosphere and Earth.




After bouncing off the Earth, the radiation has lower energy that is absorbed by greenhouse gases.

# Secondary Pollutants

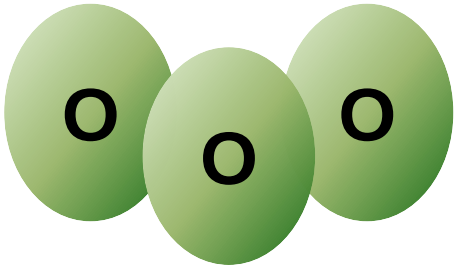
But wait! There's more!

- $NO_X$ reacts with other chemicals in sunlight to produce ozone → Ozone is called smog (brownish haze) in the lower atmosphere

- Smog and PM reduce visibility and lead to health problems (asthma, bronchitis, emphysema)

# Ozone

- ✓ Ozone is a colorless odorless gas made of oxygen.
- ✓ Ozone is $O_3$ - three oxygen atoms joined together.
- ✓ Ozone is helpful in the upper atmosphere by shielding us from ultraviolet light, but it is a component of smog in the lower atmosphere



# Conclusion

- ✓ It is impossible to eliminate harmful emissions, but… it is the responsibility of every one of us to reduce energy consumption!!

# Emission Control

**Exhaust Emissions** are produced by cars, buses, and motorcycles.

Four basic types of exhaust emissions:

1. Hydrocarbons (HC)
2. Carbon monoxides (CO)
3. Oxides of nitrogen (NOx)
4. Particulates.

# Emission Control

## Hydrocarbons (HC)

- ✓Resulting from the release of unburned fuel into the atmosphere.
- ✓Produced by incomplete combustion or by fuel evaporation.
- ✓Mostly related to ignition problems.
- ✓Effect could be eye, throat, and lung irritation, and, possibly cancer.

# Carbon Monoxide (CO)

✓Extremely toxic emission resulting from the release of partially burned fuel (incomplete combustion of petroleum-based fuel).

✓CO prevents human blood cells from carrying oxygen to body tissue.

✓Symptoms are headaches, nausea, blurred vision, and fatigue.

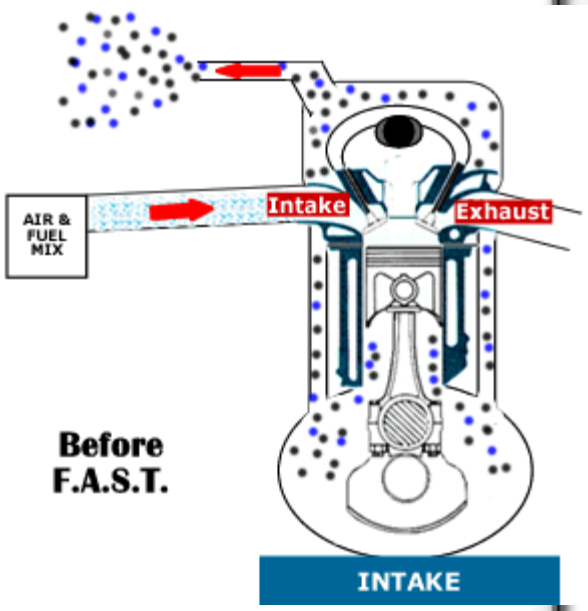
✓A rich air-fuel would increase CO; lean air-fuel mixture would lower CO emissions.

## Oxides of Nitrogen (NOx)

- ✓Produced by extremely high temperatures during combustion.
- ✓Air consist of about 79% nitrogen and 21% oxygen.
- ✓With enough heat (above 2500ºF / 1370ºC), nitrogen and oxygen in air-fuel mixture combines to form NOx emissions.
- ✓An engine with high compression ratio, lean air-fuel mixture, and high-temperature thermostat will produce high combustion heat, resulting in formation of NOx.

# SOURCES OF VEHICLE EMISSONS

•**Engine Crankcase Blow-by Fumes (20%)–** and burning of fuel that blows past piston ring the crankcase.




•**Fuel Vapour (20%) –** chemica enter the air as fuel evaporate.

•**Engine Exhaust (60%)-** blown out the tailpipe when engine burns a hydrocarbon based fuel.

# Engine Modification Related to Emission Control

## Lower Compression Ratios

- Use of unleaded gasoline that permits use of catalytic converters and burns completely to lower **HC** emissions.
- Lower combustion temperature = Lower **NOx** emissions.

## Smaller Combustion Chamber Surface Volume

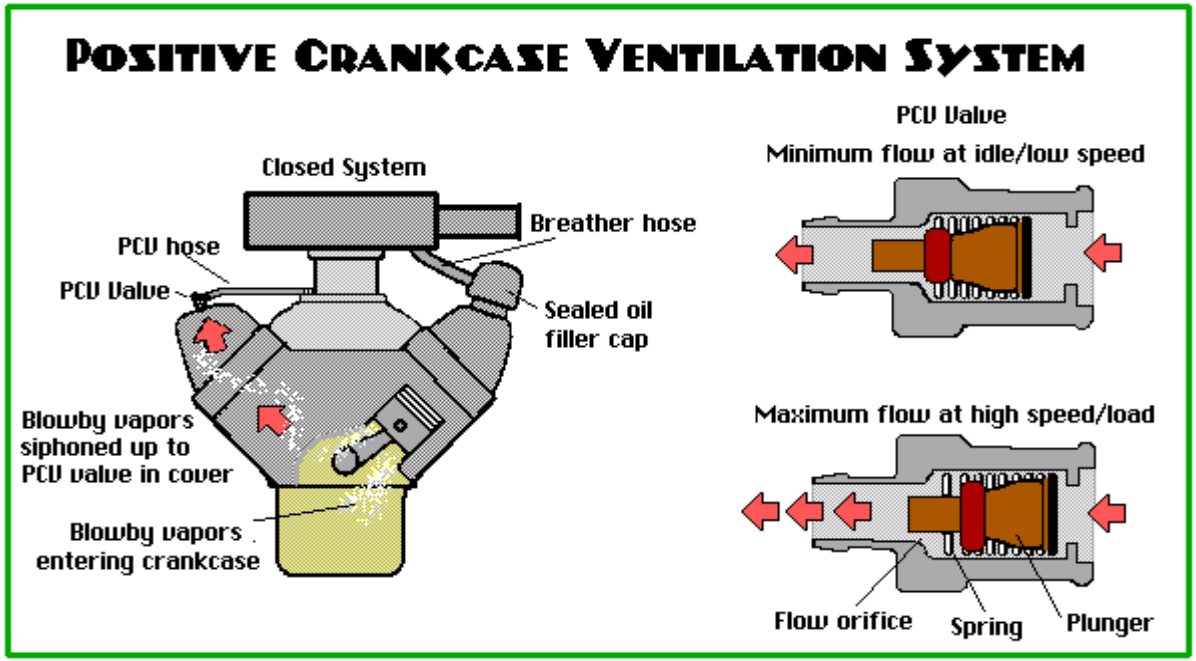
- Reduce **HC** emissions.
- Lowers the amount of heat dissipation out of the fuel mixture.
- Reduce the chance of fuel condensation.

## Reduce Quench Areas in the Combustion Chambers

- Lower **HC** and **CO** emissions.
- *Quench areas-* movement of piston too close to the cylinder head.
- If too close, it tends to quench *(put out)* combustion and increase emissions due to unburned fuel.

# Vehicle Emission Control System

## PCV (Positive Crankcase Ventilation System)




✓ Uses engine vacuum to draw blow-by gases into the intake manifold for reburning in the combustion chamber.

✓ Vacuum or electronic controlled, mounted on the valve cover.

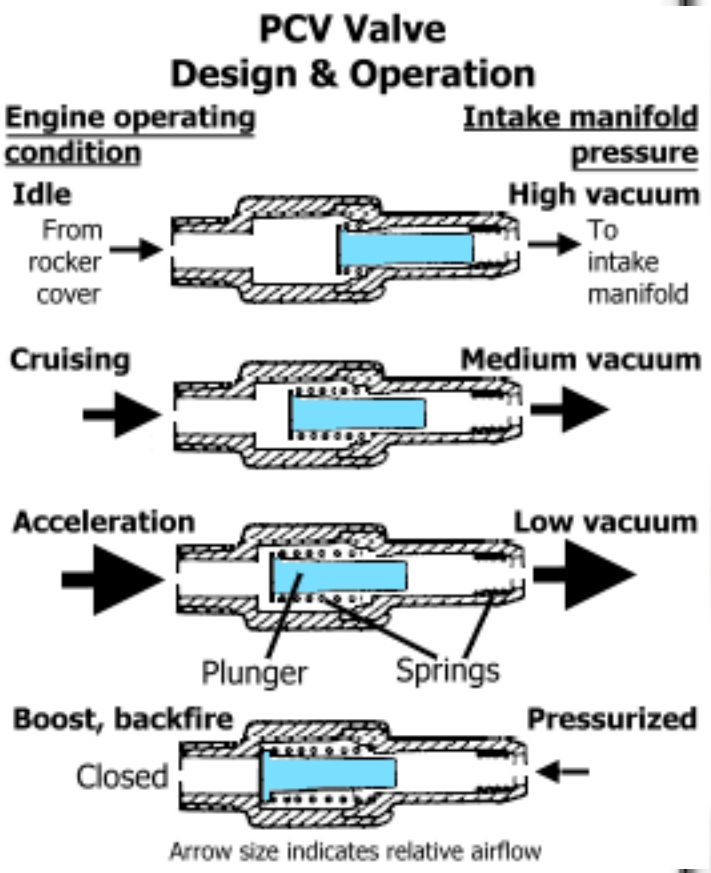
# Vehicle Emission Control System

## PCV (Positive Crankcase Ventilation System)

•At idle, high manifold vacuum pulls the plunger
for minimum vapour flow (prevents a lean air-fuel mixture).

•During acceleration, intake manifold decreases. This allows the PCV valve to move to a center position for maximum flow.

•With engine off, a spring pushes the valve against its seat, closing the valve. A backfire will also close the valve.



# Vehicle Emission Control System

## PCV System Testing

To quickly test a PCV valve, pull the valve out of the engine and shake it. If the PCV valve does not rattle when shaken, replace the valve.

With the engine running, place your finger over the PCV valve. There should be suction present (idle speed drop 40-80rpm); if not, the hose may be plugged.

# Evaporative Emission Control Systems (EVAP)

✓Prevents toxic fuel system vapours from entering the atmosphere.

## Parts

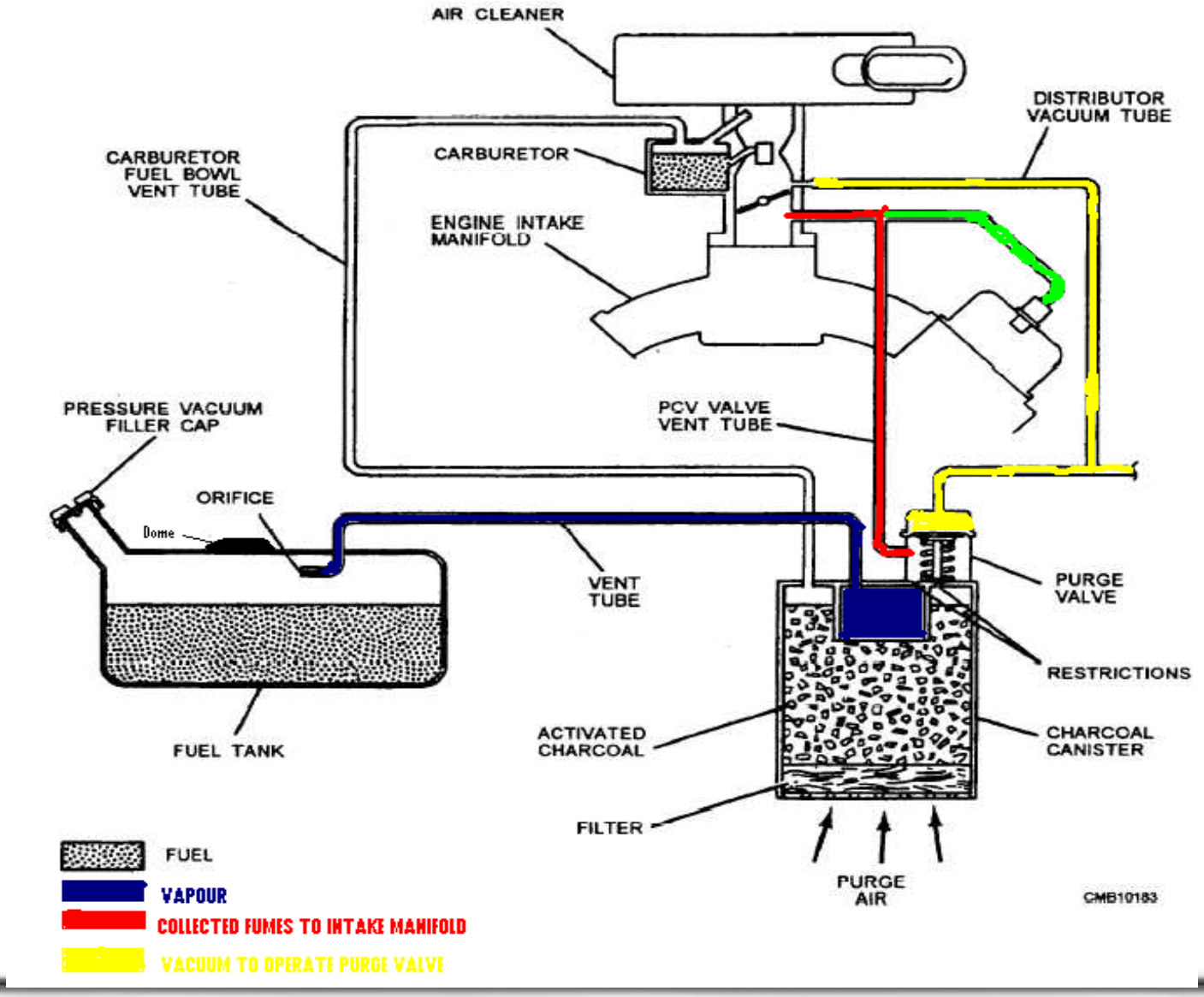
- **Non-vented fuel tank cap** – prevents fuel vapours from entering the atmosphere.

- **Air Dome** – hump formed at the top of the tank for fuel expansion.

- **Charcoal Canister** – stores vapours when the engine is not running.
  - filled with active charcoal granules.
  - charcoal is capable of absorbing fuel vapours.
- **Purge Line/Valve** – controls the flow of vapours from the canister to the intake manifold.
  - allows flow when engine reaches operating temperature and is operating above idle speed.

**Clean canister filter time to time.**

# Evaporative Emission Control Systems (EVAP)



# Exhaust Gas Recirculation (EGR)

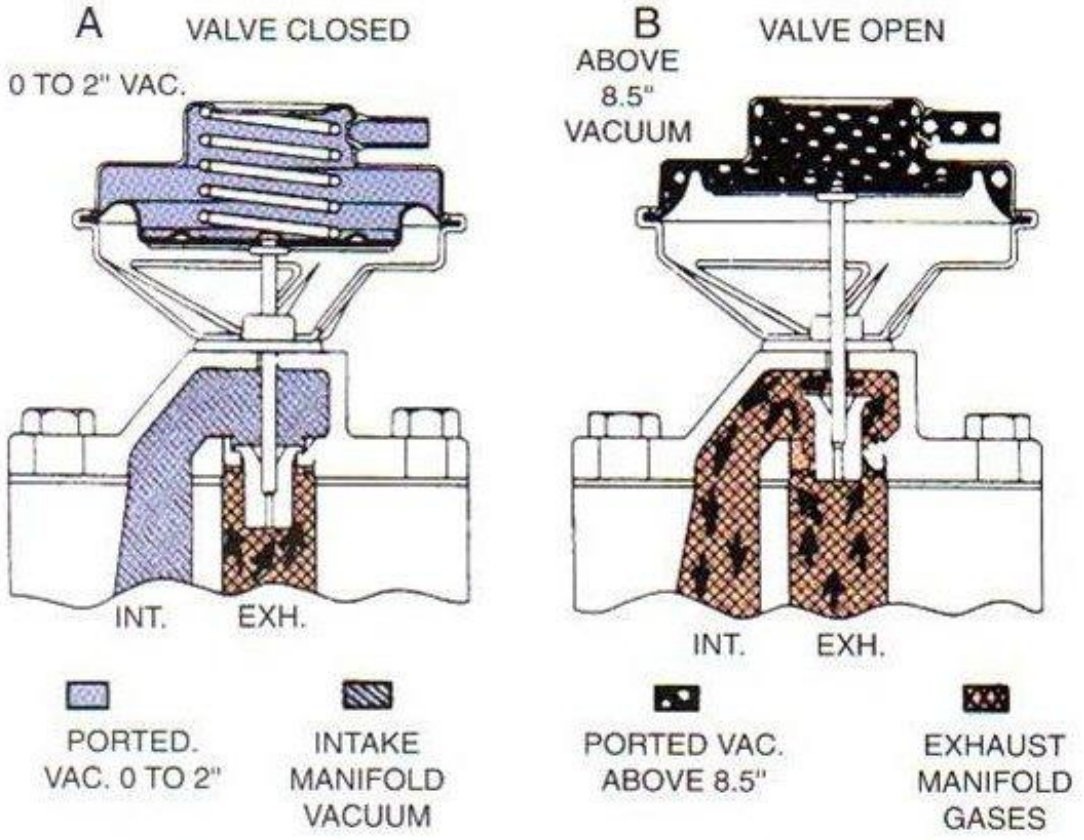
✓Allows burned gases to enter the engine intake manifold to help reduce **NOx.**

✓When exhaust gases are added to air-fuel mixture, they decrease peak.

✓ combustion temperatures.

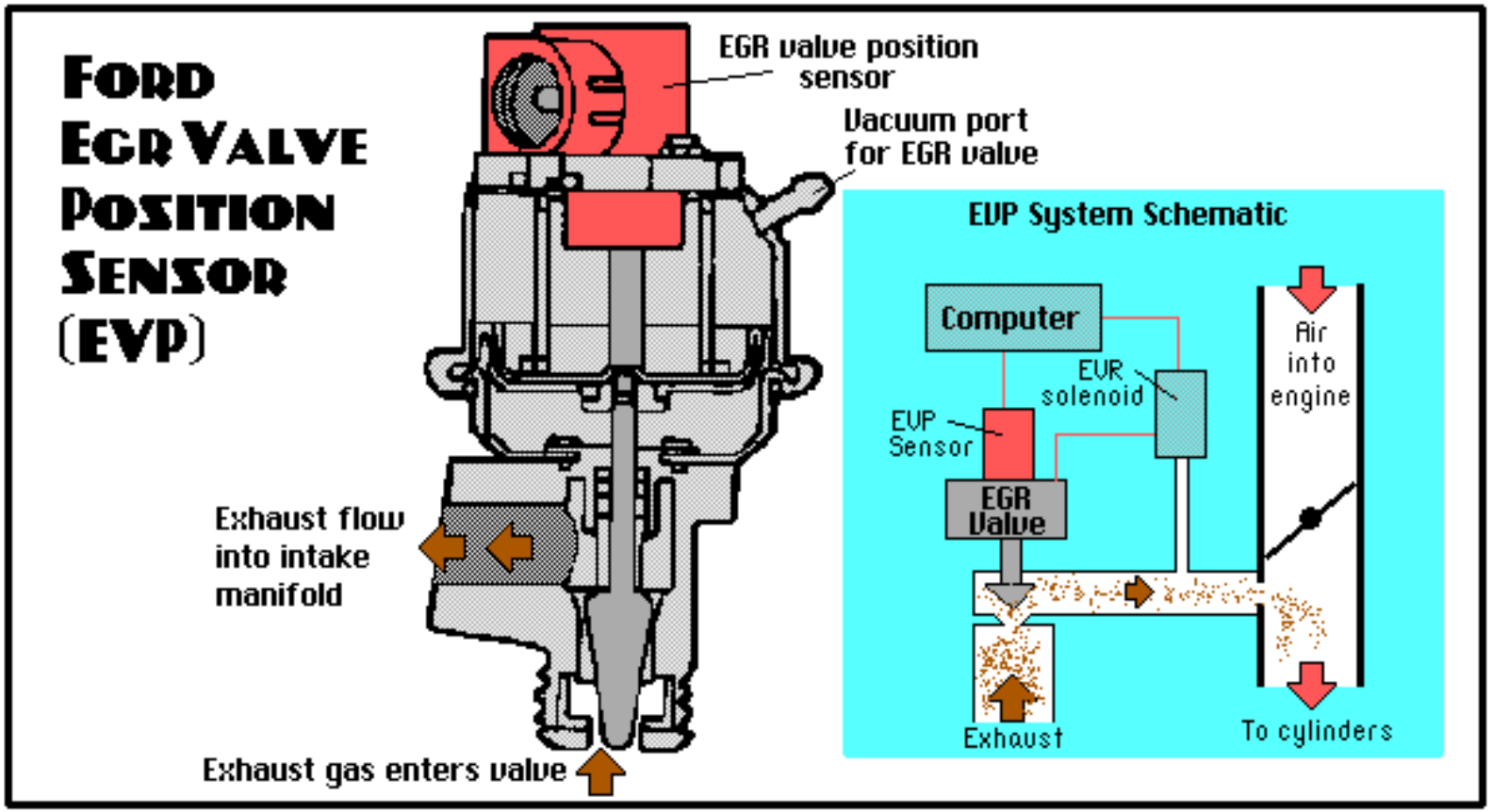
# Exhaust Gas Recirculation (EGR)

**Vacuum operated (Throttle Vacuum)** When accelerated the throttle plate opens, engine vacuum is applied to EGR, opening the diaphragm. Engine exhaust can enter the intake manifold and combustion chamber.



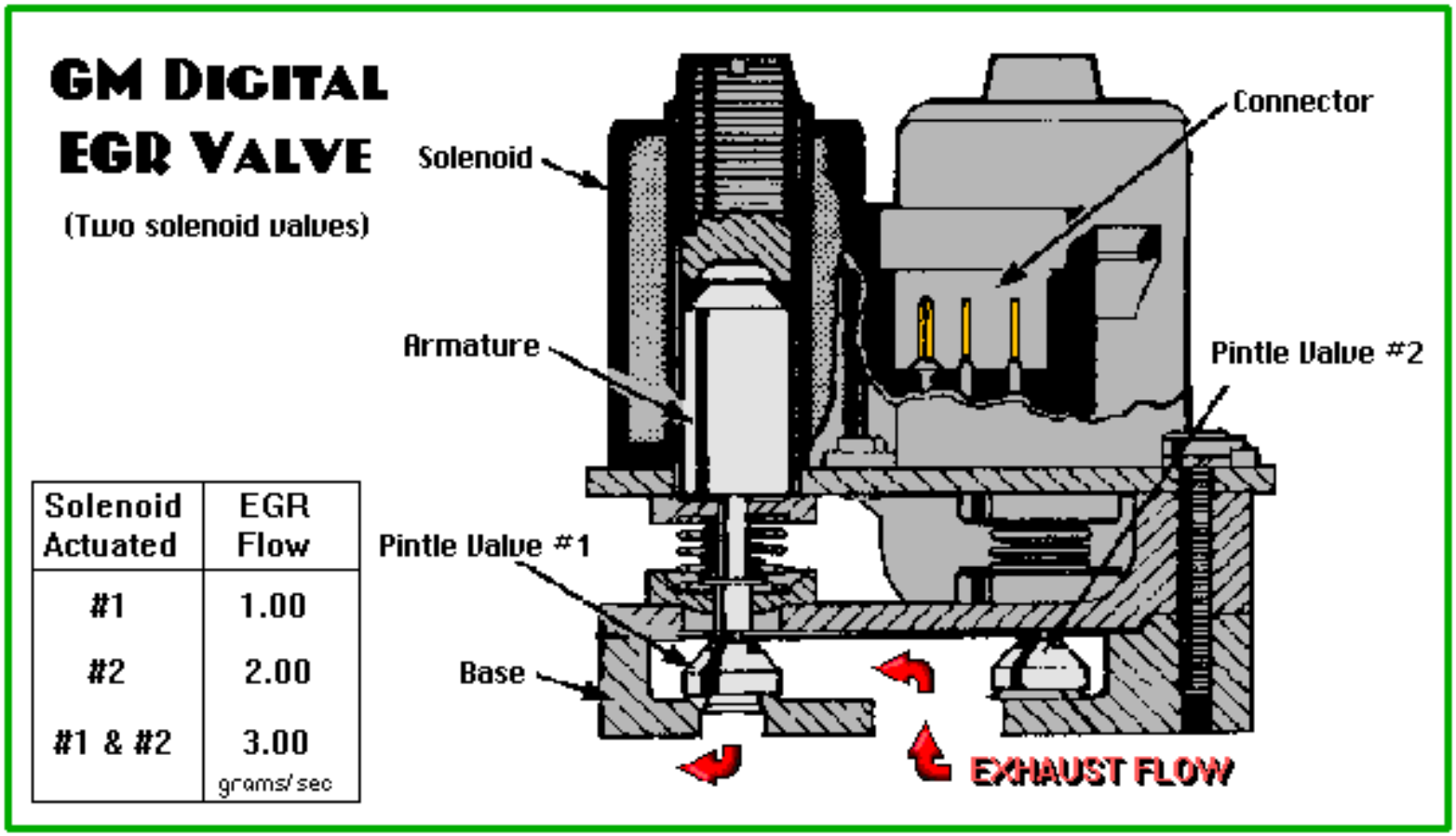
# Exhaust Gas Recirculation (EGR)

**Electronic-Vacuum EGR Valve** uses both engine vacuum and electronic control for better exhaust gas metering.



# Exhaust Gas Recirculation (EGR)

**Electronic EGR Valve** uses one or more solenoids to open/close exhaust passages.



## EGR System Service

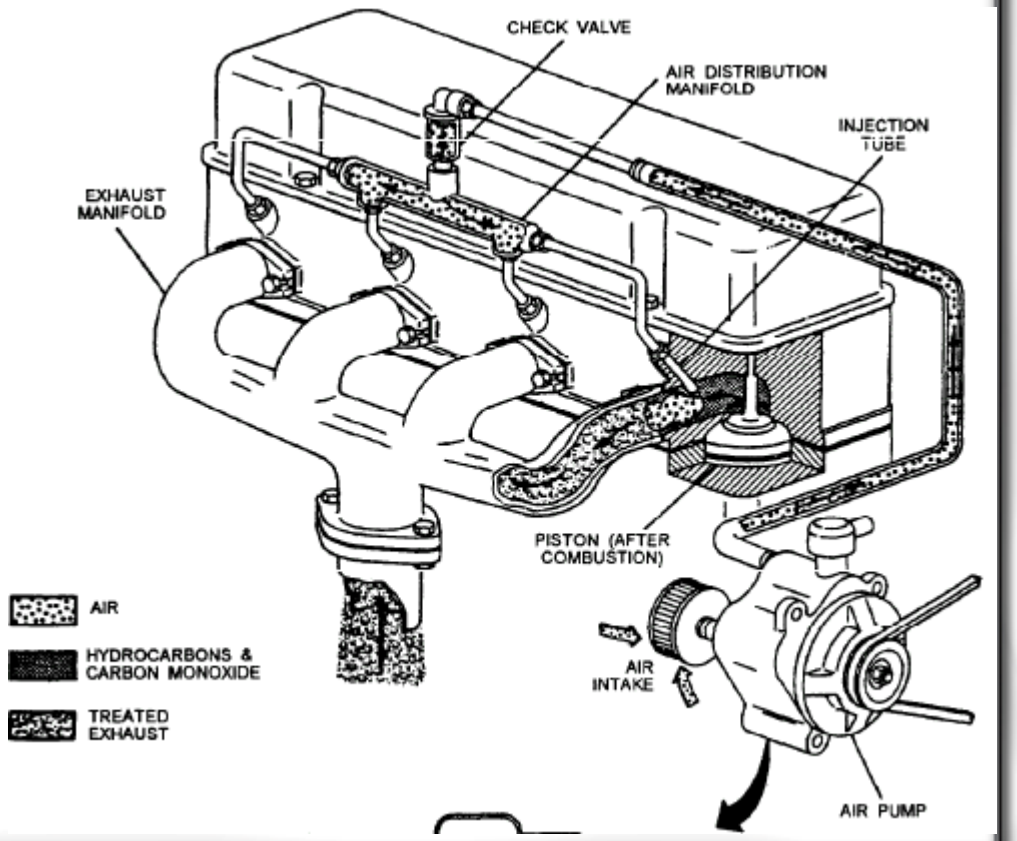
✓System malfunction can cause stalling, rough idle, detonation, and poor fuel
economy.

✓If stuck open, it will cause a lean air-fuel mixture, engine will run rough at idle, or stall.

✓If stuck closed, higher combustion temperatures can cause abnormal combustion and knocking, raising **NOx**.

# Air Injection System

- ✓Forces fresh air into the exhaust ports or catalytic converter to reduce **HC/CO**.
- ✓Oxygen from the air injection system causes the unburned fuel to burn in the exhaust system or the catalytic converter.



## Catalytic Converter

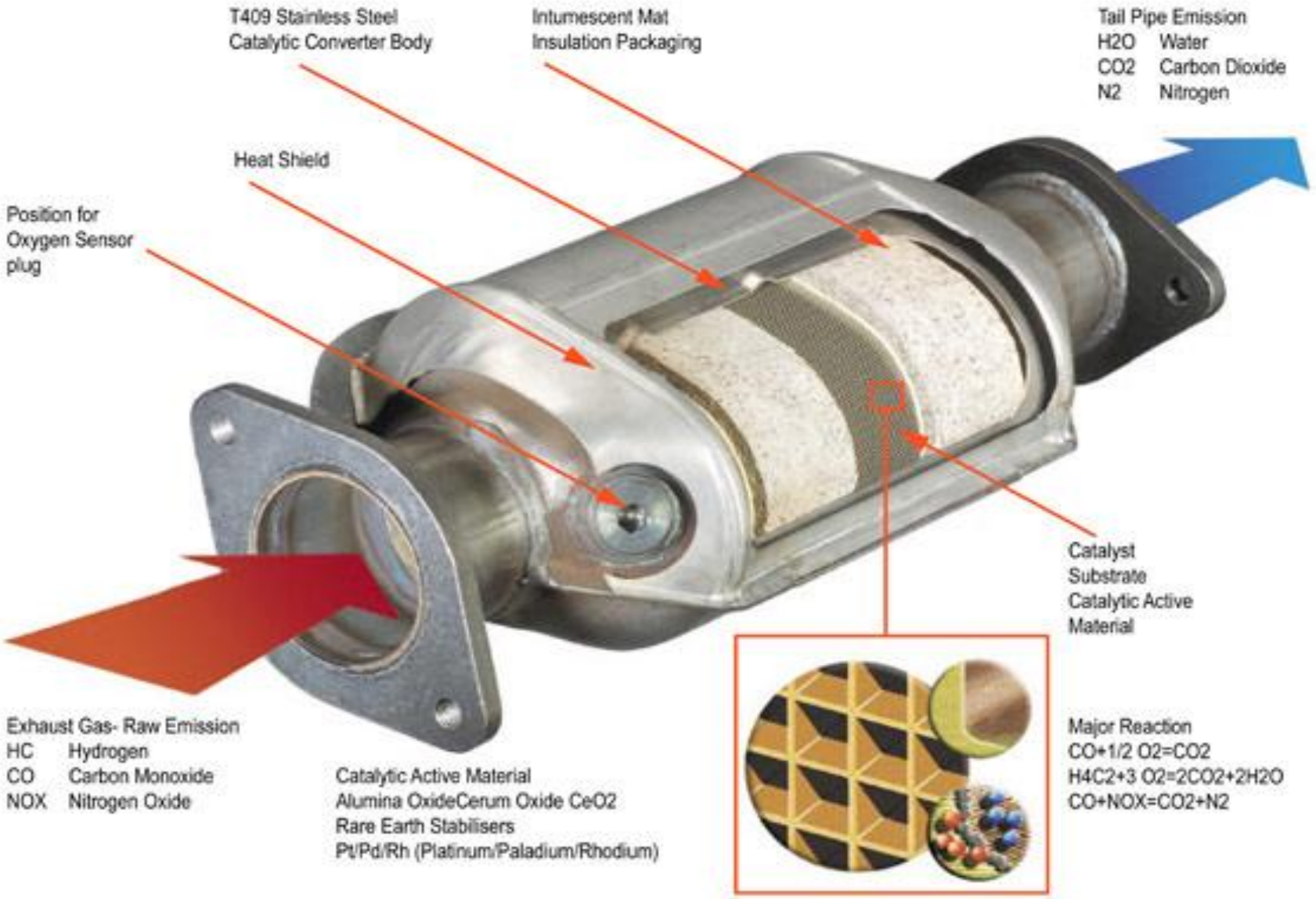
✓Oxidizes (burns) the remaining **HC** and **CO** emissions that pass into the exhaust system.

✓Extreme heat (1400°F/760°C) ignites these emissions and change them into carbon dioxide (**$CO_2$**) and water (**$H_2O$**).

✓**Catalyst** is a substance that speeds a chemical reaction without itself being changed (coated with ceramic honey comb).

✓**Catalyst Substance**: Platinum and Palladium treats **HC** and **CO** emissions; Rhodium acts on the **NOx** emissions.

# Catalytic Converter



# Photochemical smog…

# Photochemical smog ??

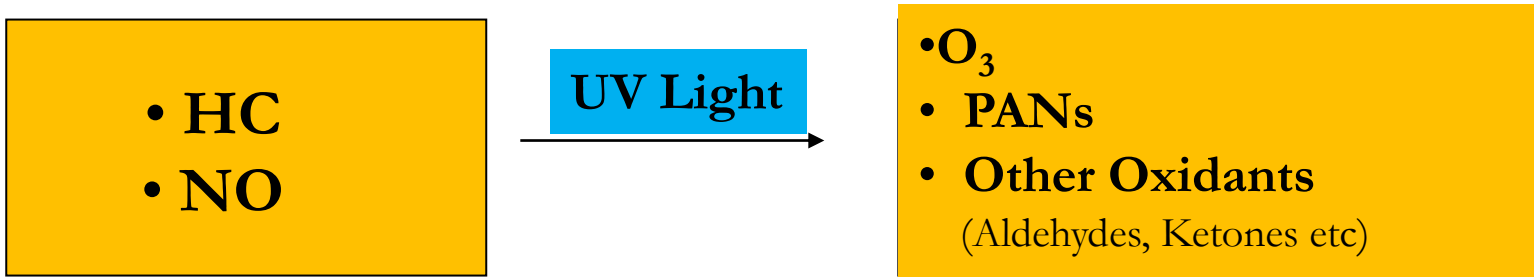
Noxious mixture of highly reactive and oxidizing air pollutants including:

- Oxides of Nitrogen ($NO_x$)
- Volatile organic compounds
- Troposphere Ozone
- Peroxyacetyl Nitrates (PAN)

# Generation Mechanism:

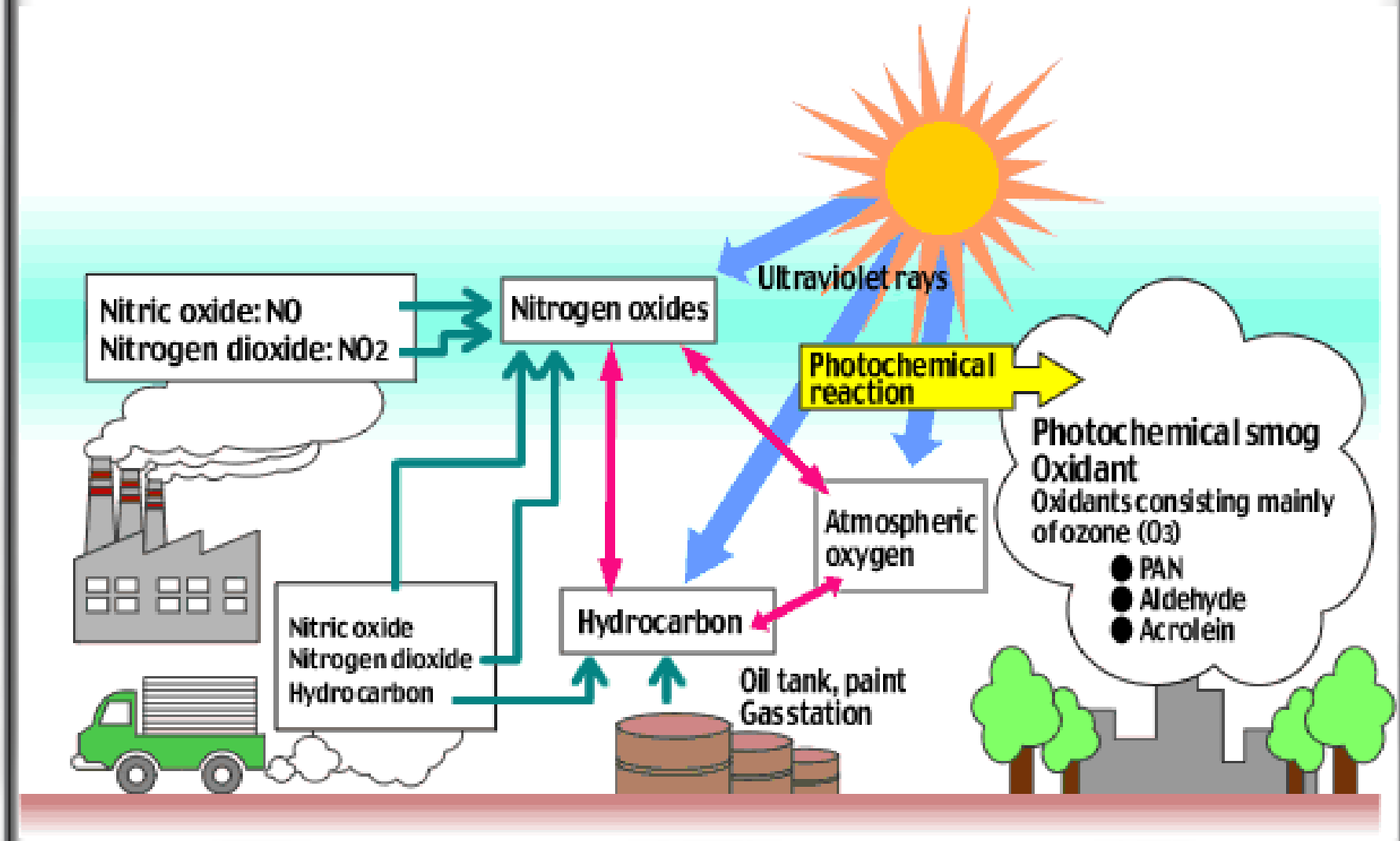
Three ingredients required:

- Ultraviolet Light
- Hydrocarbons
- Nitrogen oxides




***Photochemical Reaction***

# Generation Mechanism contd..



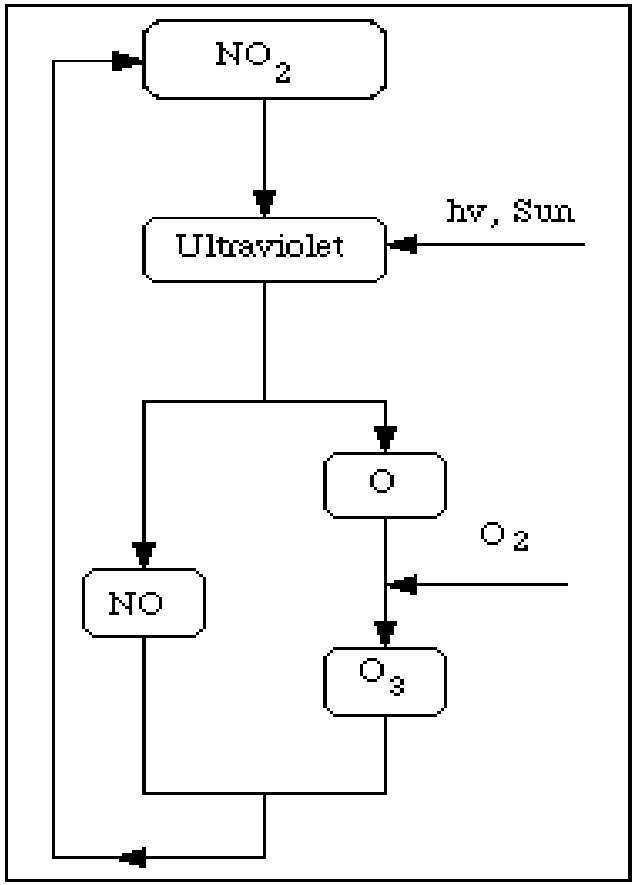
# Photochemical Reactions

Troposphere Ozone:

- $NO_2 + h\nu \longrightarrow NO + O$
- $O + O_2 \longrightarrow O_3$

Sources:

- Exhaust gases From Motor vehicles
- Unborn Hydrocarbons



# Photochemical Reaction Contd..

## Volatile Organic Compounds (VOC)

Carbon-based molecules such as Aldehydes,

Ketones and Hydrocarbons

$$RCH_3 + 2O_2 + 2NO \longrightarrow RCHO + 2NO_2 + H_2O$$

## Sources:

- Paint thinners, solvents and petroleum constituents
- Trees: emits isoprene and terpenes
- Methane from termites, cows and cultivation

# Photochemical Reaction Contd..

Peroxyacetyl Nitrates (PAN)

Are secondary pollutants formed from peroxyacid radicals and $NO_2$

- $CH_3CHO + OH^{\bullet} \longrightarrow CH_3C^{\bullet}O + H_2O$
- $CH_3C^{\bullet}O + O_2 \longrightarrow CH_3C(O)OO^{\bullet}$ (acetylperoxy)
- $CH_3C(O)OO^{\bullet} + {}^{\bullet}NO_2 \longrightarrow CH_3C(O)OONO_2$ (PAN)

# Effects on human health

- ✓Ozone
  - Cause acute respiratory problems
  - Aggravate asthma
  - Cause temporary decreases in lung function in healthy adults
  - Lead to hospital admissions and emergency room visits
  - Impair the body's immune system
- ✓Peroxyacetylnitrate (PANs)
  - Respiratory and eye irritants
  - Mutagenic- causing skin cancer

# Effects on human health contd..

- ✓ Volatile organic compounds (VOCs)
  - Global warming- Methane
  - Carcinogenic- benzene
  - Form Ozone

# Future engines and fuels...

# Alternative Energy Cars

An alternative fuel vehicle is a vehicle that runs on a fuel other than "traditional" petroleum fuels, and also refers to any technology of powering an engine that does not involve running solely on petroleum. Also, it has increasingly began to refer to vehicles that are very fuel efficient.

Looking at 3 specific types of energy efficient cars:

- Battery Electric
- Hydrogen Cell
- Hybrid Electric

# Pros and Cons

- Overall, Environmentally responsible

- Fewer to no emissions depending on vehicle type

- Less use of non-renewable resources

- Tax incentives

- Complex system- more likely to break down

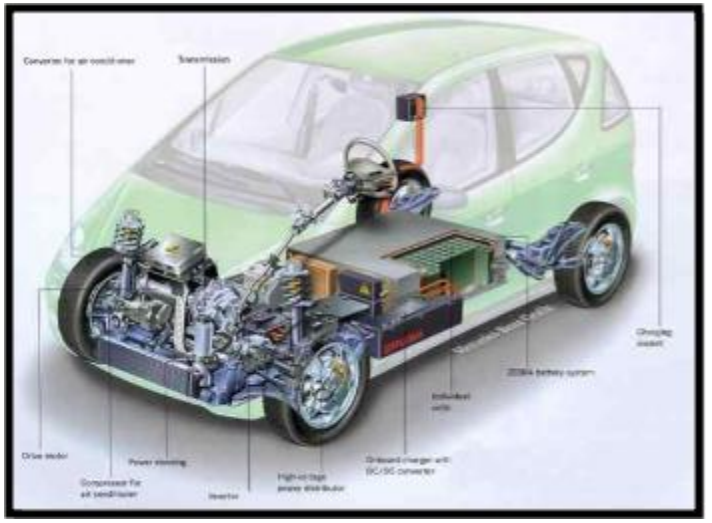
- Higher initial price of car,

- Higher cost to fix compared to that of regular cars

- Possible inconvience

# Battery Electric Cars

- ✓Electric motor and motor controllers
- ✓Low running costs compared to gasoline cars
- ✓High energy efficiency
- ✓Regenerative braking
- ✓Charge range



# Battery Electric Cars

- ✓Reduced carbon dioxide emissions
- ✓No pollution at the tailpipe
- ✓Charging time depends on the type of battery and power grid
- ✓Battery Lifespan

# Hydrogen Cell Cars

- ✓ Alternative fuel car that uses hydrogen as its onboard fuel.
- ✓ Reacts hydrogen with oxygen in a fuel cell to run electric motors
- ✓ Sequel—a fuel cell-powered vehicle from General Motors

# Hydrogen cell cars

- ✓ Hydrogen fuel is not naturally occurring, but can be produced from multiple sources
  - Wind, solar and nuclear
- ✓ Issue lies with the current fact that the energy content per unit volume is too low to be efficient
  - Meaning not enough energy for the amount of fuel needed

# Hybrid Electric Vehicles

- ✓ Most common form is the hybrid electric car
- ✓ Combines conventional internal combustion engine (ICE) propulsion system with electric compulsion system
- ✓ Can be fueled with gasoline, diesel, hydrogen, or biofuels

# Hybrid Electric Vehicles

- ✓ Technology
  - regenerative braking
  - electric motor drive/assit
  - automatic start/shutoff
- ✓ Different degrees of hybridization
- ✓ Environmental Impact
  - low fuel consumption and pollution
  - little noise
  - raw materials

# Future Green Cars

- ✓ Solar Power
  - Solar panels harvest solar energy from sunlight
  - Photovoltaic Cells (PV's) in panels convert sunlight to electricity
- ✓ Biodiesel
  - Fuel comprised of natural ingredients (corn, soybeans, animal fat, etc.)
  - Usually mixed with normal diesel fuel
- ✓ Super capacitors
  - Like a rechargeable battery without memory degradation
  - Recharge at electrical stations

# Future Car Obstacles

- ✓ Solar
  - Way in which cars are stored
  - High PV cost and lifetime
- ✓ Biodiesel
  - Increase in NOx emissions resulting in increase in smog
  - Decrease in power
  - Amount and availability of biodiesel
- ✓ Super capacitors
  - Practical EESU's are still in the works
  - Fast recharge stations would need to be developed and made available to consumers


Any
Questions