Laboratory Safety

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Recognition of Hazards

- Physical
- Biological
- Chemical

Health Hazards Vs Safety Hazards

- Health ≠ Safety

- Safety concerns: Imminent Danger
- Health concerns: Health Effects

Physical Hazards

- Noise
- Heat Stress
- Fire
- Burn
- Cut
- Pressure
- Ionizing and Nonionizing radiation

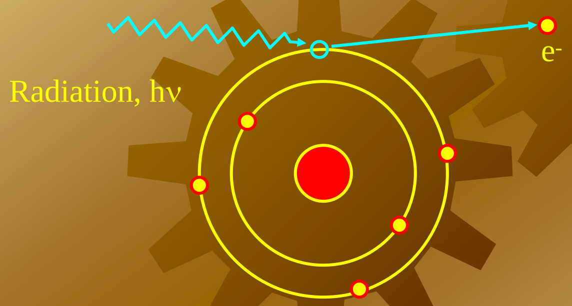
Physical Hazards in Laboratory

- Burn
  - Hot plate, burner, glassware
    - Malfunctioning equipment (thermostat)
    - Incompatible accessories (rubbing tubing)
    - Improper procedure
- Cut
  - Scalpel, broken pipette, broken glass, needle stick
    - Conditions of the tool
    - Housekeeping
    - Users' training

Physical Hazards in Laboratory (cont.)

- Pressure
  - Gas cylinder, pressurized equipment or setup
    - Pressure test
    - Pressure relief device
    - Flashback arrestor for flammable gases
- Ionizing radiation
  - Energy emitted from radioactive atoms, and have sufficient energy to overcome the binding energy between an electron and an atom to cause ionization.

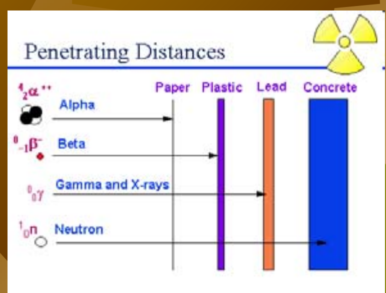
Ionization



- Ionization is the removal of an electron from an atom or an ion, resulting in an ion pair.
- Ionization is the primary cause of radiation-induced biological damage.

Basic Types of Ionizing Radiation and Their Hazards

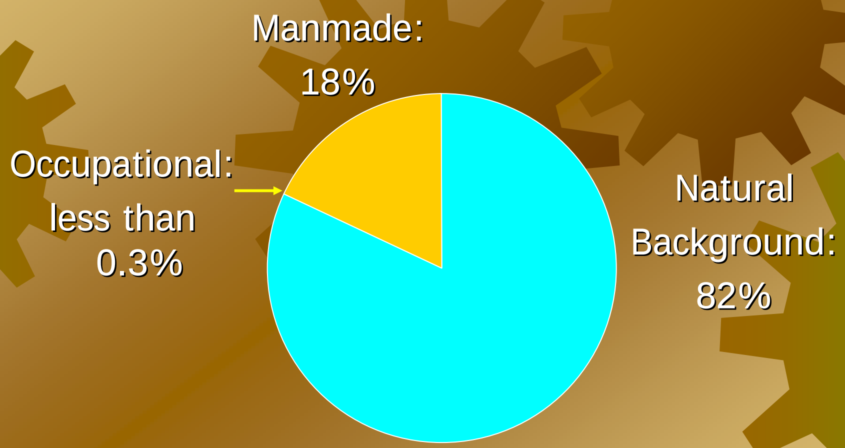
- Alpha, Beta, Gamma/X ray, Neutron
- External Hazard:
  - Gamma/X > Beta > Alpha
- Internal Hazard:
  - Alpha > Beta > Gamma/X



Factors Affecting Biological Damage

- Total Dose
- Dose Rate
- Types of Radiation
- Area of the Body Irradiated
- Cell Sensitivity
- Individual Sensitivity

Radiation Doses from Different Sources



Sources of Radiation: Man-made

- The 4 major sources of man-made radiation exposure are:

1. Medical Radiation
2. Radioactive Fall out
3. Consumer Products
4. Industrial Applications

Principles of Radiation Protection

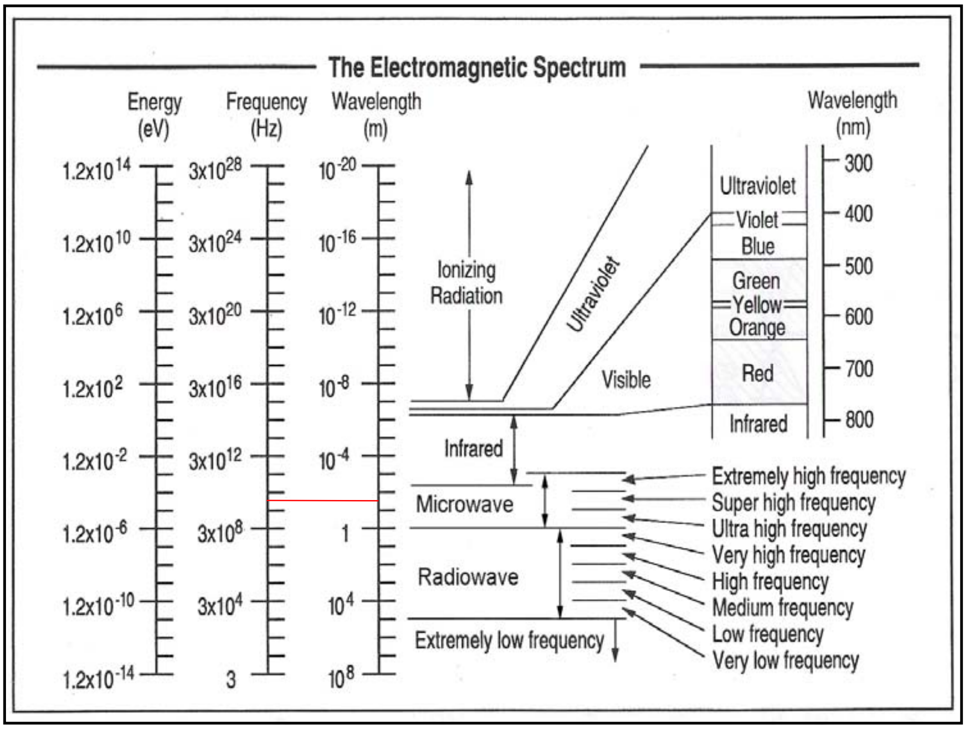
- Time
  - Plan carefully to reduce exposure time
- Distance
  - Remote operation if needed
- Shielding
  - Lead shield, Plexiglass

Existing Controls

- Using low activity, sealed radiation sources
- Store in lead save
- Conduct regular leak test
- Apply standard laboratory practices

Nonionizing Radiation

- Non-Ionizing radiation
  - Radiation that does not have the amount of energy to ionize an atom is non-ionizing radiation (NIR), e.g. microwaves, UV lights, Laser.



Ionizing versus Non-ionizing Radiation

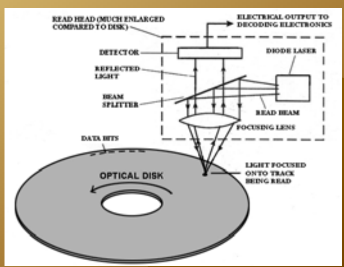
- Ionization is the main mechanism for damage by radiation (such as x-ray and gamma)
- RF/MW radiation does not have sufficient energy for ionization: it is non-ionizing radiation
- We know ionizing radiation increases cancer risk at high dose. No dose response relationship has been substantiated for non-ionizing radiation
- Compare the energy:
  - Co-60 photon: about 1 MeV
  - Microwave energy: about 10^{-5} eV (100,000,000,000 times less than that of the energy of the Co-60 photon)

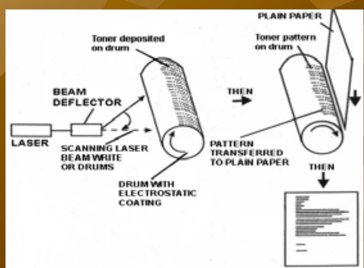
Energy levels associated with ionizing radiation are many orders of magnitude higher than that of the energy levels of non-ionizing radiation

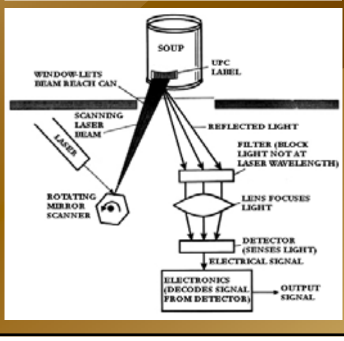
Laser

- Laser - acronym
  - Light Amplification by Stimulated Emission of Radiation
- Laser - a safety definition:
  - A highly collimated source of extremely intense monochromatic electromagnetic radiation

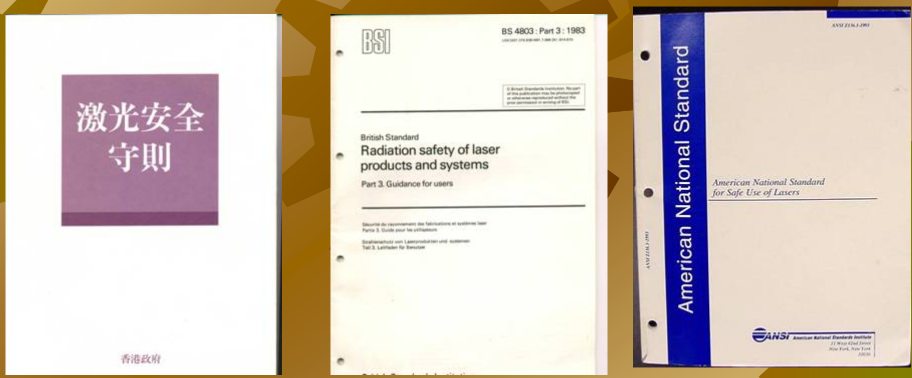
Laser Application







Standards



Laser Classification

- Classification based on the ability of the primary laser beam to cause biological damage to the eye or skin.
- There are four laser classes.

Laser Classification (cont.)

- ***Class I***
  - *Accessible laser radiation < Class I AEL for 100 s*
  - *Considered to be incapable of producing damaging radiation levels during operation*
  - Not hazardous, even if output is gathered by optics
  - Exempt from any control or other forms of surveillance

*Maximum Permissible Exposure (MPE) The maximum level of radiation to which human tissue may be exposed without harmful effect. MPE values are found in the ANSI Standard Z136.1 2007
*Class I Accessible Emission Limit (AEL) = MPE * Area irradiated

Laser Classification (cont.)

- ***Class II***
  - Emits in the visible portion of the spectrum (0.4 to 0.7 um)
  - Average power < 1 mW;
  - Less than Class I AEL for pulse duration < 0.25s
  - Eye protection is normally afforded by the aversion response.
  - Hazard would exist if viewer stifled aversion reflexes, i.e. blinking and looking away.

Laser Classification (cont.)

- ***Class III – Moderate-Power Laser***
  - Can cause harm to eye in less time than it takes to blink (1/4 second), skin and diffuse reflection hazards not important

Laser Classification (cont.)

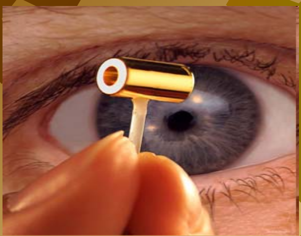
- ***Class IIIR***
  - 1-5 times Class I AEL (<0.4 um, >0.7 um)
  - 5 times Class 2 AEL (> 0.4 um, <0.7um)
  - Potentially hazardous under some direct and specular reflection viewing condition
  - Not harmful at a glance, collecting optics needed to cause harm

Laser Classification (cont.)

- ***Class IIIB***
  - < 0.4um, >1.4 um
    - Average power <0.5 W T<0.25 s
    - 0.15 J T<0.25 s
  - 0.4um to 1.4 um
    - Average power <0.5 W T<0.25 s
    - 0.03 C_A J per pulse
  - May be hazardous under direct and specular reflection viewing conditions
  - Bare beam could injure eye

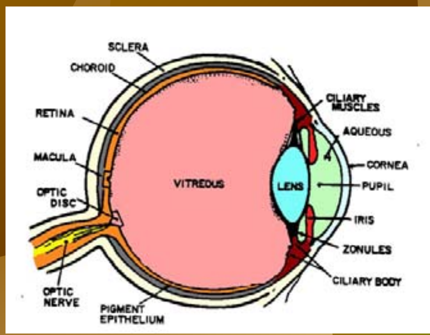
Laser Classification (cont.)

- ***Class IV High-Power Laser***
  - Can cause eye damage by diffuse reflection, also skin injury and fire hazard
  - May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation
  - This class requires serious controls.



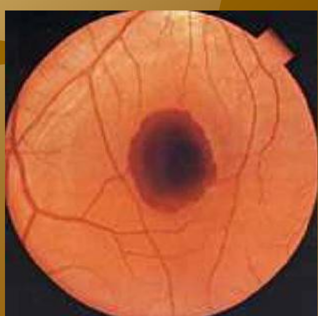
Laser Hazards

- Beam Hazard
  - Eye
  - Skin
- Electrical
- Dye
- Gas
- Other hazards



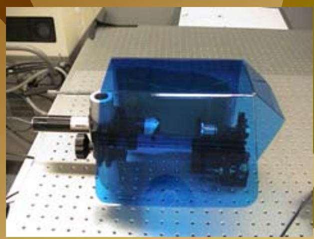
Beam Hazards

- Exposures to laser beam can cause severe eye injury.



Principles of Laser Protection

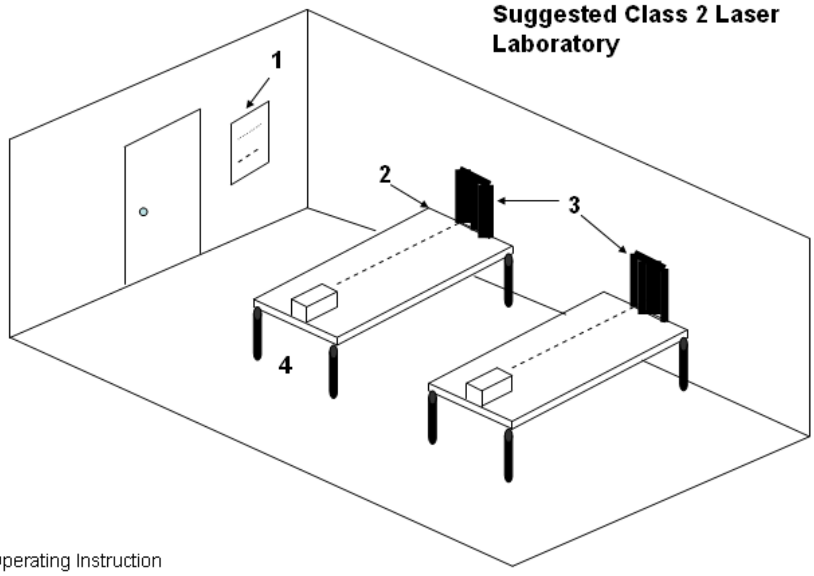
- Minimize laser power
- Prevent laser beam from leaving the designated work area
- Enclose beam path as much as possible
- Secure laser below eye level
- Training
- Follow manufacturer's instruction and establish Safe Operation Procedure.



Beam Control (cont.)

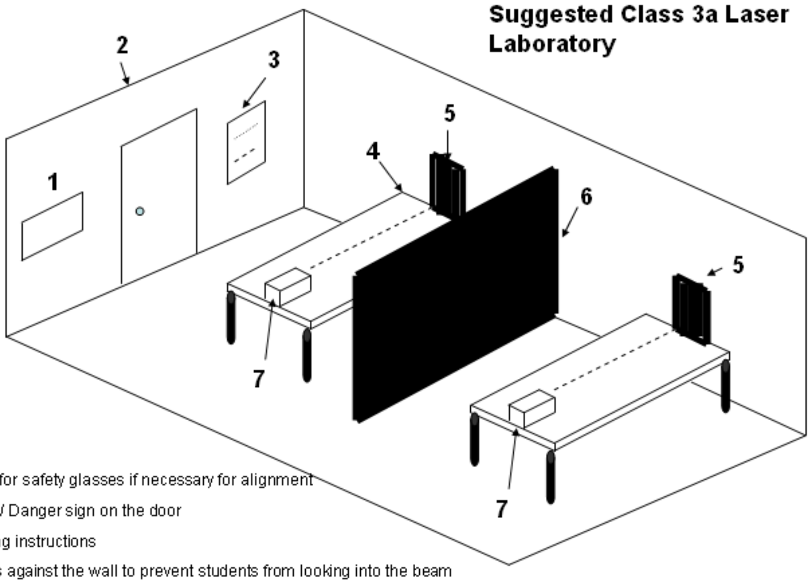
Beam Control (cont.)

Suggested Class 2 Laser Laboratory



1. Operating Instruction
2. Benches against the wall to prevent students from looking into the beam
3. Beam stops to prevent reflection of the laser beam
4. Multiple class 2 lasers in the rooms

Suggested Class 3a Laser Laboratory



1. Cabinet for safety glasses if necessary for alignment
2. Caution / Danger sign on the door
3. Operating instructions
4. Benches against the wall to prevent students from looking into the beam
5. Beam stops to prevent reflection of the laser beam
6. Wall separating laser stations
7. Multiple class 3a lasers in the laboratory

Safe Use of Laser Pointers

- Do not point laser at any individual
- Do not view laser beam directly or its specular (mirror-like) reflection
- Use Class II laser pointer (< 1mW)
- Control access

Radiation: Issues and Concerns

- Medical Physics: X-ray and ultrasounds
- Using Green Laser Pointer for teaching
- Using microwaves

Biological Hazards

Definition of Biohazards

Biological agents or substances which present a hazard to human health or well being.

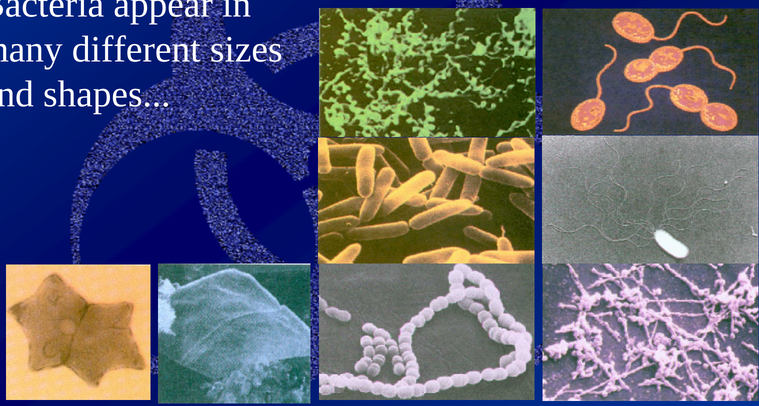
These include certain bacteria, fungi, viruses, rickettsiae, chlamydiae, parasites, recombinant DNA products, allergens, cell cultures, toxins and clinical specimens.

Biological Hazards

- Infectious agents
  - Microorganisms and arthropod vectors
  - Clinical specimens (blood-borne pathogens)
  - Cell cultures
  - Experimental materials (e.g. sewage)
  - Indoor air
- Laboratory animals
- Biological toxins
- Recombinant DNA molecules

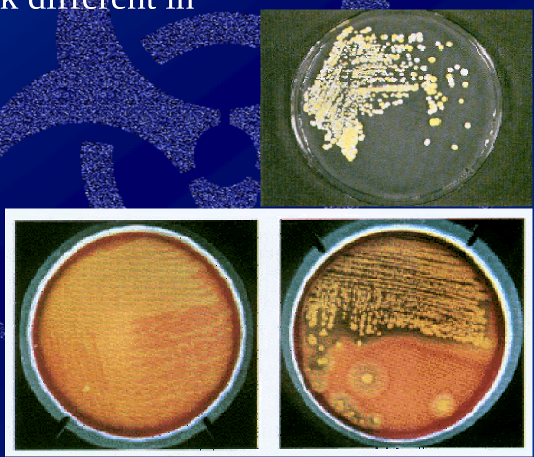
Bacteria

- Bacteria appear in many different sizes and shapes…



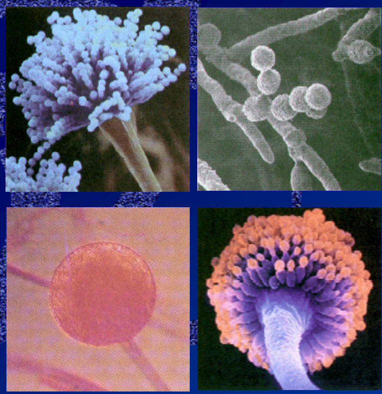
Bacteria (cont.)

- They look different in colonies



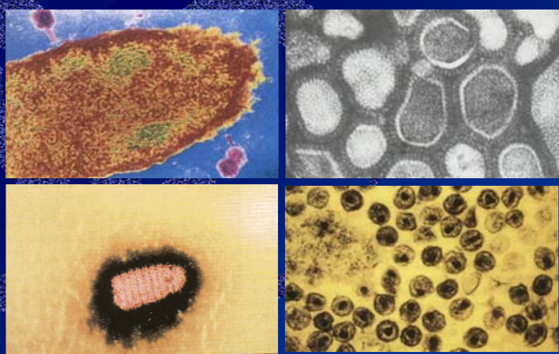
Fungi

- Fungi look like miniature plants



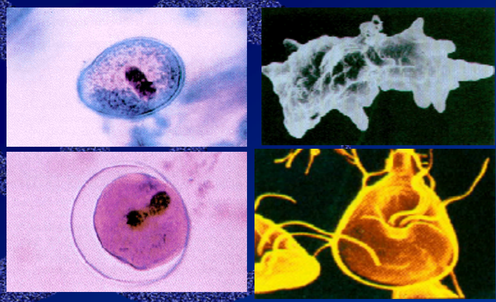
Virus

- Viruses are submicron sized intracelluar parasites



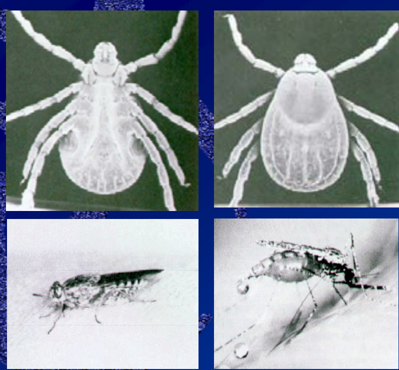
Protozoa

- There are many kinds of protozoan pathogens.



Arthropod

- Many types of arthropods which are vectors of pathogens



Infectious Agents--Clinical Specimens

- Blood borne pathogens are the major concern
  - Hepatitis B Virus (HBV)
  - Human Immunodeficiency Virus (HIV)
  - Viruses causing other hepatitis, e.g. HCV
- Clinical specimens of blood-containing organs and bodily fluids other than blood can also carry significant amount of pathogens

Infectious Agents--Experimental Materials

- Many experimental materials, such as environmental samples, may contain biological agents
- Freshwater, seawater, wastewater, sewage samples
- Soil, sediment, sludge samples
- Food samples

Infectious Agents--Indoor Air

- Bacteria--Legionnaire's Disease
  - *Legionella pneumophila*
- Fungus
  - *Stachybotrys chartarum*
  - *Aspergillus sp.*
  - *Penicillium sp.*
- Fungal effects: allergic, pathogenic, toxic
- Sick Building Syndrome

Laboratory Animals

- Physical injuries inflicted by the animals, such as bites and scratches
- Zoonoses, i.e. diseases that infect both animals and humans
  - indigenous, i.e. naturally carried by the species
  - experimentally introduced
- Allergens of animal origins
- Other introduced hazards, such as chemicals and radiation

Others

- Biological toxin
  - Saxitoxin, Botulinum toxin, Tetrodotoxin
- Recombinant DNA Molecules
- Cell cultures
  - Cancer cell lines, virus infected cell lines

Classification of Biohazards

- Class I
  - all non-pathogenic microbes
- Class II
  - Pathogenic microbes
  - Diseases are easily treatable if recognized early
- Class III
  - Highly infectious pathogenic microbes
  - Diseases can be serious and life threatening
- Class IV
  - Highly infectious pathogens that can easily spread in the community
  - Diseases are often fatal

Exposure Pathways

- Air
  - Droplets
  - Bioareosols
- Contact
  - Casual or intimate
  - Contaminated materials
- Animal or insect vectors

Common Routes of Exposure

- Oral (ingestion)
  - Eating, drinking and smoking
  - Mouth pipetting
  - Contaminated fingers or articles
- Respiratory (inhalation)
  - Contact with infectious materials from spill, sprays, aerosol
  - Aspiration through pipette
  - Inhalation of airborne microorganisms
    - Sources:
      - Operation of centrifuges, ultra-centrifuges, homogenizers, Culture stirrers, shakers, agitators

Common Routes of Exposure (cont.)

- Percutaneous (skin penetration)
  - Injury caused by broken glass, sharp objects or needle stick
  - Animal bite or scratch

General Principles to Prevent Occupational Infections

- Ingestion route
  - frequent hand washing
  - proper use of gloves
  - no eating or drinking in lab
- Inhalation route
  - avoid aerosol generation
  - contain aerosol generating processes
- Skin penetration
  - proper handling and disposal of sharps

Engineering Controls for Biohazards

- Primary Barrier mainly achieved by Biological Safety Cabinets
- Secondary Barrier by facility features
  - isolated/sealed rooms
  - special ventilation, e.g. pressure regime, air locks, HEPA filtered air exhaust
  - special drainage, e.g. holding tanks
  - waste disinfection facilities
  - other features, e.g. UV lamp

Engineering Control

Biological Safety In Teaching Laboratories

Biohazards Associated with Teaching Laboratories

- Dissection
  - Cut, needle stick injury
  - Contracting biohazardous agents
- Control
  - Source
  - Use proper PPE
  - Cover wounds
  - Disinfection and disposal of sharp
  - Personal hygiene

Biohazards Associated with Teaching Laboratories (cont.)

- Handling live animal
  - Bite and scratches
- Control
  - Source
  - Immunization, consultation, medical surveillance
  - Hands-on training
  - PPE

Biohazards Associated with Teaching Laboratories (cont.)

- Handling biological samples including blood samples
  - Exposure to blood-borne pathogens
- Control
  - Source
  - Adopt Universal Precautionary Principle
  - Minimize aerosol generation e.g avoid centrifugation and aspiration procedures
  - PPE
  - Personal hygiene

Biohazards Associated with Teaching Laboratories (cont.)

- Handling plants
  - Toxic species
  - Allergens
- Control
  - Source
  - Hypersensitive individual (avoid contact)

Biohazards Associated with a Typical Molecular Biology Experiment

- Cell culture
  - Aseptic technique
- Host cell
  - Infectious cell lines?
- Vector
  - Self-replicating?
- DNA Insert
  - Nature of the insert, size of the insert, type of end products produced?

Biohazard: Issues and Concerns

- Quality of the biological samples
  - Infection, contaminations
- Take special precaution when handling potentially infected biological materials
  - Blood, organs (swine flu, chicken flu, BSE)
- Substitute procedures involving significant risk
  - Aerosols generating procedures
- Training
  - Standard microbial manipulation technique
  - Aseptic technique
  - Universal Precautionary Principle


Biohazard: Issues and Concerns (cont.)

- Proper disposal of biological wastes
  - Disinfection, sterilization
- Be familiar with the hazards associated with Electrophoresis
  - Staining agents, electric shock, Gel preparation, disposal

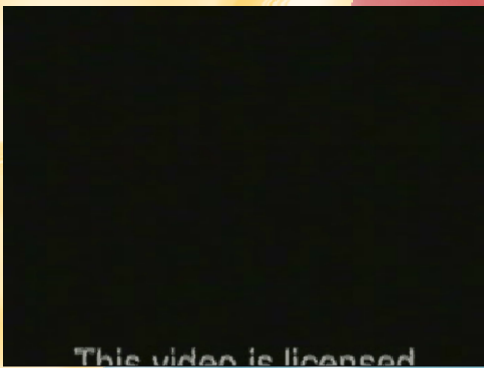


Chemical Safety

Case Study: Laboratory Fire Kills UCLA Researcher

- A 23-year-old research assistant working at UCLA who was seriously burned in a lab fire in December 2008 recently died from her injuries.
- She was trying to transfer up to 2 ounces (~50ml) of t-butyl lithium (pyrophoric chemical), which was dissolved in pentane from one sealed container to another by a 50 ml syringe.
- The barrel of the syringe was either ejected or pulled out of the syringe, causing liquid to be released.
- A flash fire set her clothing ablaze and spread second- and third-degree burns over 43% of her body.

Fire Hazard of Pyrophoric Chemical



Case Study: Mixing of Incompatible Wastes

- A user disposed 300 ml of acid waste into a waste container
- He then capped the lid and put the container into a flammable cabinet.
- After half an hour, he heard an explosion next door

Case Study (cont.)

Case study: Explosion of picric acid

Picric acid with water content less than 40% is classified as explosives

http://www.info.gov.hk/gia/general/200103/06/0306213.htm

Explosion of Picric Acid (cont.)

Chemical Hazards in Laboratories

- Pyrophorics -- yellow phosphorous
- Water reactives -- sodium metal
- Peroxidizables -- ethyl ether, tetrahydrofuran
- Shock sensitives -- anhydrous picric acid
- Cryogens -- liquid nitrogen, dry ice
- Flammables -- organic solvents
- Asphyxiants -- inert gas such as nitrogen

Chemical Hazards in Laboratories

- Corrosives -- sulfuric acid, sodium hydroxide
- Toxics -- formaldehyde, nickel compounds
- Oxidizers -- potassium permanganate

Remember

READ your Material Safety Data Sheet before you start!

Be prepared for emergency

Chemical Safety: Controls

- The idea is to avoid any contact with chemicals by:
- Substitution
- Minimize quantity
- Isolation
- Personal Protective Equipment (PPE)

Controls

- Perform experiment involving chemicals in a fume hood.
- Use PPE such as chemical-resistant gloves and safety glasses

Performance of the Safety Equipment

- Fume Cupboard
  - Containment
    - Leakage
    - Visual test (dry ice)
  - Capturing
    - An average face velocity of 0.5m/s (BS Standard: >0.3m/s)
    - Performance Indicator
    - Maintenance contract

Selection of PPE

- Compatible gloves
  - Nitrile, butyl rubber, latex
- Safety glasses vs safety goggles

Observation

- Storage of chemicals
  - Spill containment, spill tray
  - Inadequate exhaust ventilation
  - Spill clean up kit
- Fume cupboard
  - Understanding the working principle of the fume cupboard
  - Proper maintenance

New Challenge

- Trying to accommodate more
  - Demand for more supervision, equipment
- More hands-on laboratory work at earlier age
  - Skill, discipline
- Training for staff

Suggestion

- Start laboratory induction for students at junior forms
  - Help develop a safety culture
- Require senior students to perform risk assessment
  - Develop a habit of finding out the risk, hazards associated with the laboratory work and the necessary preventive measures needed.

In Summary

- A good habit could save a bright scientist in the making.