

Biomedical
Science

Molecular
Genetics



BMS 34010A | Fall 2026-2027

Biotechniques

Medical Laboratory Biosafety



Free Session

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Biosafety, Biosecurity & Biocontainment

Biosafety

The principles, technologies, and practices implemented to prevent **unintentional exposure** to pathogens or their accidental release.

Focus: unintentional risks — spills, needlesticks, aerosol generation

Implementation: PPE, engineering controls, administrative controls, training, and standard operating procedures

Biosecurity

Measures to prevent **loss, theft, misuse, or intentional release** of pathogens.

Focus: intentional threats — sabotage, bioterrorism, insider threat

Measures: access control, personnel reliability, inventory management, restricted information sharing

Biocontainment

The **physical and procedural containment** of pathogens to prevent their escape from the lab environment.

Biological Safety Cabinets (BSCs)

Sealed rooms with negative air pressure

Air filtration

Double-door entry systems

Biocontainment is a **critical part of biosafety**, especially at higher biosafety levels.



The Biohazard Symbol

The biohazard symbol is used to mark **biological substances** that:



- Contain **infectious agents** — bacteria, viruses, fungi, parasites
- Could cause **disease in humans or animals**
- Pose **contamination risks** to the environment or to laboratory / clinical personnel



Other Common Hazard Symbols



TASK IN YOUR OWN TIME

Find out which of these are **relevant to the biomedical lab**, and what they mean.



Biosafety Level (BSL) Classifications

Biosafety levels are a series of protections ranked from **1 (lowest risk) to 4 (highest risk)** that are implemented in laboratory settings to protect **personnel, the environment, and the public** from exposure to infectious agents.

Each level is defined by specific **containment practices**, **safety equipment**, and **facility design**.



**BSL-1 & BSL-2****BSL-1 — minimal risk**

Work with **well-characterized agents** not known to cause disease in healthy humans, e.g. Escherichia coli (non-pathogenic strains).

Requires: standard microbiological practices (hand washing, no eating in lab), **lab coat, gloves, eye protection.**

BSL-2 — moderate risk

Work with agents associated with human disease but with **limited risk of aerosol transmission.**

Examples: Staphylococcus aureus, Salmonella spp., Hepatitis B virus, HIV.

Requires: all BSL-1 practices plus limited access, biohazard signs, sharps precautions, lab coat, gloves, face protection.

Equipment: autoclave needed; **Biological Safety Cabinets (BSC)** for aerosol-generating tasks.

**BSL-3 & BSL-4****BSL-3 — high risk**

Agents may cause **serious or potentially lethal disease via inhalation.**

Examples: Mycobacterium tuberculosis, SARS-CoV-2.

Requires: controlled access, decontamination of all waste, PPE and **N95 respirator**. Physical separation from access corridors, directional airflow, BSCs required.



N95
respirator

N95 respirator

BSL-4 — highest risk

Dangerous or new agents with **high risk of life-threatening disease**, often without known treatment or vaccine.

Example: Ebola virus.

Requires: all BSL-3 practices, plus clothing change before entry, shower on exit, full isolation procedures, and a **full-body, air-supplied positive pressure suit**.



Full-body, air-supplied positive pressure suit

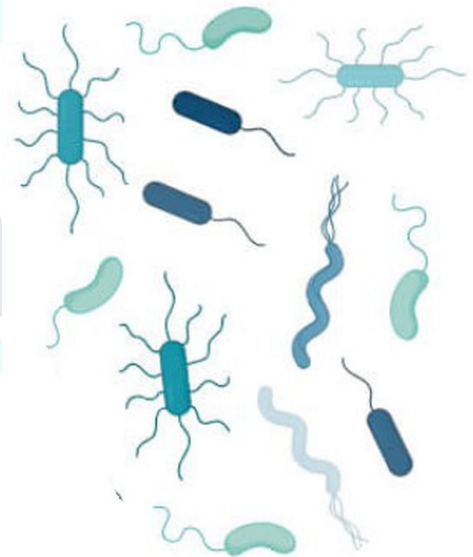
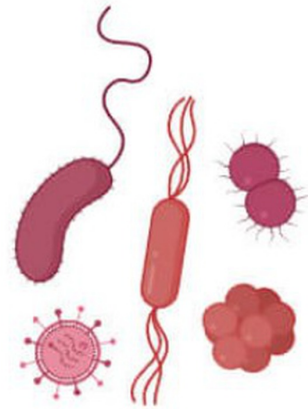


Risk Groups

Risk Groups (RGs) classify microorganisms based on their **risk to human health and the environment.**

PRIMARILY CONSIDERING

- 1 **Pathogenicity** — ability to cause disease
- 2 **Mode of transmission**
- 3 **Availability of treatment** or prophylaxis
- 4 **Likelihood of community spread**



Risk groups are typically defined from **RG1 (lowest risk)** to **RG4 (highest risk)**.



Biosafety Level vs Risk Group

While the **risk group** of a pathogen informs the BSL, the correlation is **not one-to-one**.

The straightforward case

A **Risk Group 2** agent (e.g. Salmonella) is generally handled under **BSL-2** conditions.

The exception

Risk Group 3 agents (e.g. Mycobacterium tuberculosis) may sometimes be handled at **BSL-2 with additional precautions**.

DEPENDING ON

- i The **nature of the work** — e.g. non-culture diagnostic tests
- ii The **likelihood of aerosol generation**
- iii The **volume and concentration** of the organism

Biosafety level is a function of both the organism and the lab activity being performed.



Biological Safety Cabinets (BSC)

Class I

Protects **personnel and environment** — but **not the sample**.

Class II

Most commonly used in **BSL-2/3 labs**; protects **personnel, environment, and sample**.

Class III

Fully enclosed, **glove-box type**; used in **BSL-4**.



Class I



Class III



Biological Hazards in the Clinical Laboratory

These are **pathogenic microorganisms or biological substances** that pose a risk to human health and can be encountered during the **handling, processing, or disposal** of clinical specimens.

TYPE OF BIOLOGICAL AGENT	EXAMPLES	ASSOCIATED INFECTIONS
Bacteria	Mycobacterium tuberculosis, Salmonella	Tuberculosis, enteric fever
Viruses	HIV, HBV, HCV, SARS-CoV-2	AIDS, hepatitis B/C, COVID-19
Fungi	Candida spp., Aspergillus spp.	Candidiasis, aspergillosis
Parasites	Plasmodium spp., Toxoplasma gondii	Malaria, toxoplasmosis
Prions	PrP ^{SC} (abnormal prion protein)	Creutzfeldt-Jakob disease
Biological toxins	Botulinum toxin, Shiga toxin	Botulism, Hemolytic Uremic Syndrome

THESE AGENTS MAY BE PRESENT IN

Blood and other body fluids

Tissue biopsies

Respiratory secretions

Urine or stool specimens

Culture isolates



Routes of Exposure in Clinical Laboratories

ROUTE	EXAMPLE IN LAB CONTEXT	PROTECTIVE MEASURES
Percutaneous skin puncture	Needlestick injuries, broken glass cuts	Safe sharps disposal, safety-engineered devices
Mucosal eyes, nose, mouth	Splash during centrifugation or pipetting	Face shields, goggles, mask use
Inhalation aerosol exposure	Opening culture plates, vortexing, centrifuging	BSCs, sealed centrifuge cups, masks
Ingestion	Eating / drinking in lab, mouth pipetting (still a risk)	Good lab habits
Skin contact non-intact skin	Exposure to contaminated surfaces	Use of gloves, hand hygiene



Risk Factors Contributing to Exposure

1**High sample volumes**

In busy hospital laboratories.

2**Lack of training or awareness****3****Improper use of PPE****4****Poor laboratory layout or ventilation****5****Equipment failure or misuse**

For example, malfunctioning centrifuges.

6**Human error**

For example, mislabeling or inappropriate decontamination.



Waste Management: Classification & Segregation

- 1 Identify categories: **infectious, pathological, sharps, non-infectious**
- 2 Segregate waste **at the point of generation**
- 3 Use **colour-coded, leak-proof, puncture-resistant** containers
- 4 Prevent **cross-contamination** and ensure **traceability**



<https://www.kelvinindia.in/blog/biomedical-waste-management-and-its-importance/>



Waste Management: Handling, Storage & Disposal

Wear **PPE** when handling biological waste

Store in **secure, labeled areas** with limited access

COMMON DISPOSAL METHODS

Autoclaving

Infectious waste

Incineration

Pathological waste

Chemical disinfection

Liquids

Follow **national and local regulations.**



Environmental & Public Health Implications

- 1 Improper disposal risks: **infection, pollution, disease outbreaks**
- 2 Laboratories hold **ethical & legal responsibility**
- 3 Ensure regular **training, audits, and compliance monitoring**
- 4 Supports **infection prevention** and **environmental protection**



Fun Time: “Biosafety Escape Challenge”

“You are trapped in a biomedical laboratory after a series of **biosafety breaches**. To escape, your team must solve the challenges, fix the mistakes, and collect the code pieces. The first team to escape wins!”

HOW IT RUNS

- 1 Divide into **teams of 4–6**.
- 2 Each challenge = **1 code piece** — a number, word, or symbol.
- 3 Keep track of your **clues**.
- 4 At the end, assemble them to unlock the **final escape code**.





To Summarise...

TERMS

3

Tell them apart

- Biosafety — unintentional exposure
- Biosecurity — intentional threats
- Biocontainment — stopping escape from the lab

LEVELS

1–4

Biosafety levels

- BSL-1 minimal, BSL-2 moderate risk
- BSL-3 high risk via inhalation; N95 required
- BSL-4 highest; positive pressure suit

CABINETS

3

Classes of BSC

- Class I — personnel and environment only
- Class II — adds the sample; BSL-2/3
- Class III — glove box; BSL-4

HAZARDS

6

Types of biological agent

- Bacteria, viruses, fungi, parasites
- Prions and biological toxins
- Found in blood, tissue, secretions, isolates

ROUTES

5

Routes of exposure

- Percutaneous, mucosal, inhalation
- Ingestion and non-intact skin contact
- Each has its own protective measure

WASTE

3

Disposal methods

- Autoclaving for infectious waste
- Incineration for pathological waste
- Chemical disinfection for liquids

THE THREAD THROUGH THE LECTURE

Biosafety level is a function of **both the organism and the lab activity** being performed — which is why a Risk Group 3 agent can sometimes be handled at BSL-2 with additional precautions.