

# Microbiology and Parasitology

## Fungi

SCI-M 227: Biochemistry Lecture

Schedule: MWF 10:00-12:00 AM & WTH 5:30-7:30 PM

Section: BSED-SCIENCE 2-B (DAY)/BSED-SCIENCE 2-2 (EVENING)

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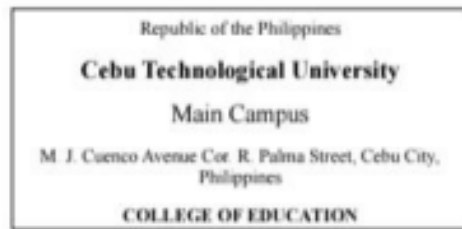
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## Introduction for Fungi

Fungi are a group of eukaryotic life forms (known as the fungus kingdom) that can be classified into 5 different divisions based on how they attain nutrients from their food, their physical structure, and how they reproduce. Fungi do not contain chlorophyll, therefore they are unable to create food from sunlight. They get nutrients from other organic sources by "eating" their organic food, often through the use of thread-like structures, called hyphae, that come together to form larger structures called mycelium. Fungi have cell walls that are made up of chitin, which is a unique component to them, and distinguishes them from plants and animals. Reproduction occurs via asexual or sexual spores, enabling them to spread throughout a large area and to colonize many different environments.

As scientists have gained a better understanding of fungi through the use of molecular biology techniques, the classification of fungi has changed substantially. Today fungi are divided into five main groups or divisions as follows: **Chytridiomycota** (the most primitive form of fungi and are known for having motile spores), **Zygomycota** (famous for producing zygospores), **Ascomycota** (the sac fungi, which include yeast and truffles), **Basidiomycota** (the club fungi, which include mushrooms and rusts), and **Glomeromycota** (form important symbiotic relationships with the roots of higher plants). Each type of fungus has different ways of reproducing and plays different ecological roles (Webster, J., & Weber, R. (2007). Introduction to fungi (3rd ed.). Cambridge University Press.).

Fungi can be broadly categorized by their ecological function. Saprophytic fungi act as decomposers, breaking down dead organic material and recycling nutrients. Parasitic fungi infect plants, animals, or humans, sometimes causing disease. Mutualistic fungi form beneficial partnerships, such as mycorrhizae with plants or lichens with algae and cyanobacteria. Beyond ecology, fungi are harnessed in industry and medicine, from fermentation processes to the production of antibiotics and enzymes. Altogether, fungi represent a kingdom of remarkable diversity and importance, shaping ecosystems and human life alike.

### Classification of Fungi:

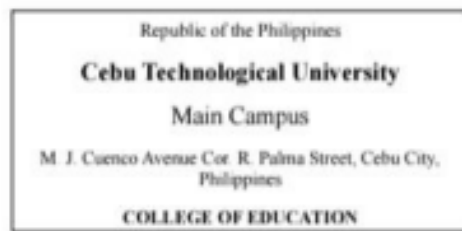
**Chytridiomycota** – simplest fungi, often aquatic, with motile spores.

**Zygomycota** – molds like *Rhizopus*, producing zygospores.

**Ascomycota** – sac fungi, including yeasts and truffles, producing spores in asci.

**Basidiomycota** – club fungi, mushrooms, puffballs, and rusts.

**Glomeromycota** – fungi forming arbuscular mycorrhizae with plant roots.



**Types of Fungi (refers to their functional or ecological roles):**

**Saprophytic fungi** – decomposers of organic matter

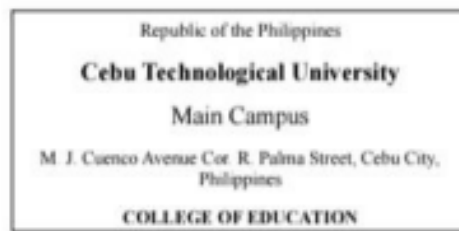
**Parasitic fungi** – pathogens of plants, animals, or humans

**Mutualistic fungi** – symbionts in lichens and mycorrhizae

**Industrial/edible fungi** – yeasts, mushrooms, and fungi used in biotechnology

**The selection of species in this study was done to illustrate common fungi present in classification and its type within various taxonomic groups.**

<b>Species</b>	<b>Classification</b>	<b>Type</b>
Rhizopus stolonifer	Zygomycota	Saprophytic mold (bread mold)
Saccharomyces cerevisiae	Ascomycota	Industrial fungi (yeast)
Agaricus bisporus	Basidiomycota	Edible fungi (mushroom)
Penicillium chrysogenum	Ascomycota	Industrial fungi (antibiotic)
Aspergillus niger	Ascomycota	Industrial fungi (citric acid)
Candida albicans	Ascomycota	Parasitic fungi (human pathogen)
Puccinia graminis	Basidiomycota	Parasitic fungi (plant rust)
Ustilago maydis	Basidiomycota	Parasitic fungi (plant smut)



## RHIZOPUS STOLONIFER



*Rhizopus stolonifer*, popularly recognized as **black bread mold**, is a cosmopolitan fungal agent categorized under the phylum Zygomycota. As one of the most common fungi in the world, it is primarily known for its rapid colonization of stored food products, such as bread and soft fruits like strawberries. While it is often viewed as a nuisance due to food spoilage, this organism plays a critical ecological role as a decomposer and is industrially significant for the production of organic acids and alcohols.

**Common Name:** Black Bread Mold **Scientific Name:** *Rhizopus stolonifer*

Figure 1. The General Morphology of *Rhizopus stolonifer* (Black Bread Mold).

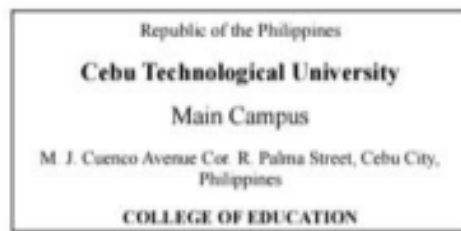
### TAXONOMY OF THE ORGANISM

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The taxonomic classification of *R. Stolonifer* highlights its complex cellular structure and heterotrophic nature:

**Domain: Eukary**

*Rhizopus stolonifer* is classified as a member of the Eukarya because it has cells that are organized into complex structures that are enclosed within membranes, along with membrane-bound nuclei and other organelles in those cells.



## **Kingdom: Fungi**

The kingdom Fungi consists of organisms that are heterotrophic. *Rhizopus stolonifer* is a mold that lacks chlorophyll, is non-motile, is filamentous, and is a decomposer of organic material.

## **Phylum: Zygomycota**

*Rhizopus stolonifer* belongs to the phylum Zygomycota because it sexually produces zygospores and is considered saprophytic and parasitic.

## **Class: Zygomycetes**

The Zygomycetes all have chitinous cell walls in a coenocytic mycelium, and they lack motile spores.

## **Order: Mucorales**

*Rhizopus stolonifer* is a member of the Mucorales because it is fast growing, with wide hyphae that lack septa or are coenocytic, and grows within a substrate. *Rhizopus stolonifer* is also considered a member of the Mucorales because it is a major saprophyte, or grows and acquires nutrients from dead and decaying matter.

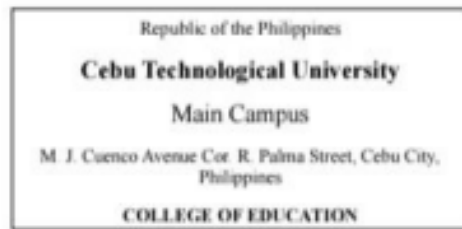
## **Family: Mucoraceae**

*Rhizopus stolonifer* is a part of the family Mucoraceae due to the key feature of a swollen extension of the sporangiophore, called the columella. It looks like a balloon within the sporangium, and it often persists after the spores have been released.

## **MORPHOLOGY/CHARACTERISTICS**

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The morphology of *Rhizopus stolonifer* is highly adapted for rapid expansion across nutrient-rich surfaces. Its appearance typically starts as a white, cottony mass that



transitions into a dark black color as the reproductive sporangia mature. Unlike many other fungi, its filaments, or hyphae, are coenocytic, meaning they are continuous tubes without septa (cross-walls).

Structure	Description	Primary Function
<b>Stolons</b>	Horizontal hyphae that arch over the surface.	Facilitates rapid horizontal spread across the substrate.
<b>Rhizoids</b>	Root-like branched hyphae growing downward.	Anchors the fungus and secretes digestive enzymes.
<b>Sporangiophores</b>	Upright, vertical aerial hyphae.	Supports the sporangia to aid in wind dispersal.
<b>Sporangia</b>	Spherical sacs containing thousands of spores.	Site of asexual reproduction and spore maturation.

## ANATOMY AND PHYSIOLOGY

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The physiology of *R. Stolonifer* centers on its role as a **saprotroph**, meaning it obtains energy by breaking down dead organic matter. Through **extracellular digestion**, the fungus secretes powerful enzymes like amylases and proteases into its environment to



degrade complex molecules into simpler units like glucose and amino acids for absorption.

## Reproductive Mechanisms

The fungus employs three distinct methods of reproduction to ensure survival and rapid colonization:

1. **Vegetative Reproduction:** This occurs through fragmentation. Small fragments form on the body surface; if a **stolon** breaks, each individual piece has the biological capacity to develop into a new, independent mother mycelium.
2. **Asexual Reproduction:** This is the most common method, occurring via sporangiospores produced within the sporangia. These spores are lightweight and easily dispersed by air currents to find new food sources.
3. **Sexual Reproduction:** When compatible (+ and -) mating types meet, they undergo conjugation to form a thick-walled **zygospore**. This structure is highly resistant and remains dormant during harsh environmental conditions until favorable states return.

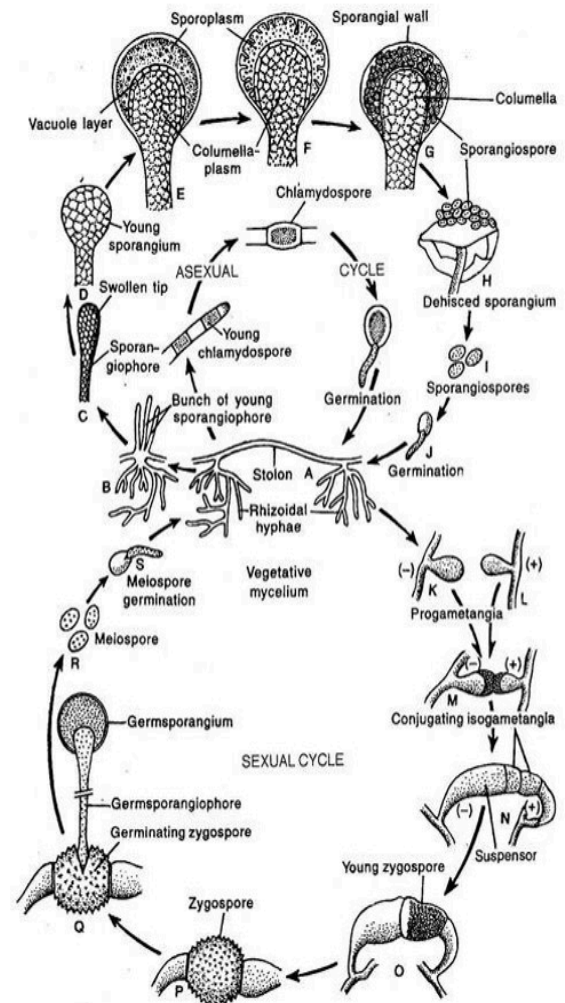
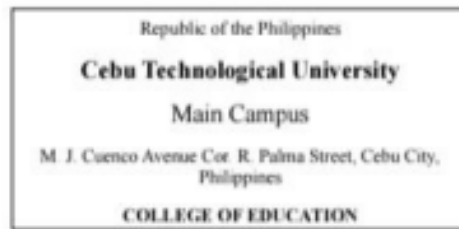


Figure 2. Life Cycle of *Rhizopus stolonifer*



## DISEASES AND BENEFITS

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*Rhizopus stolonifer* presents a dual impact, acting as a significant agricultural pathogen while simultaneously offering valuable industrial utility.

Impact Type	Example	Specific Description
Plant Pathogenesis	Soft Rot	Causes watery tissue degradation in strawberries and sweet potatoes.
Human Health	Zygomycosis	A rare but dangerous infection in immunocompromised individuals.
Industrial Use	Organic Acids	Utilized to produce commercial-grade <b>fumaric</b> and <b>lactic acids</b> .
Biotechnology	Fermentation	Involved in fermenting sugars to produce ethyl alcohol.

## LATEST TECHNOLOGY AND RESEARCH

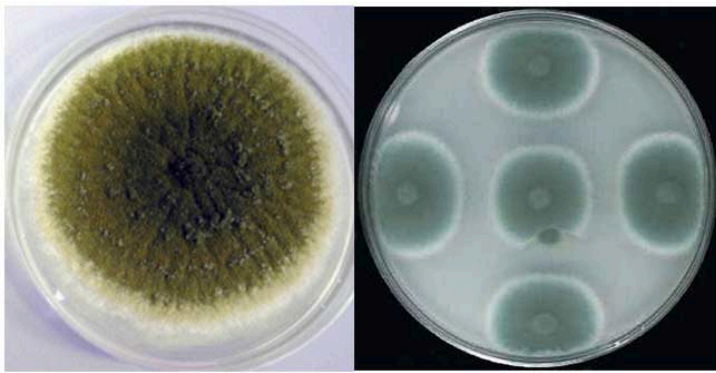
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Recent scientific advancements have focused on genomic mapping and non-chemical preservation methods to combat the economic losses caused by this fungus in the agricultural sector.

- **Genomic Mapping (2025):** Researchers have identified 33 specific oxidoreductases and 7 proteases that form the "infection toolbox" of *R. stolonifer*, explaining how it rapidly liquefies plant tissues during infection.



- **Non-Thermal Plasma (NTP):** New technology using atmospheric plasma is being developed to sterilize fungal spores on fresh produce without the need for chemical fungicides or heat treatment.
- **Waste Valorization:** Studies demonstrate that the fungus can be used in **Solid-State Fermentation (SSF)** to turn agricultural waste, such as cocoa pod husks, into high-value animal feed rich in proteins.

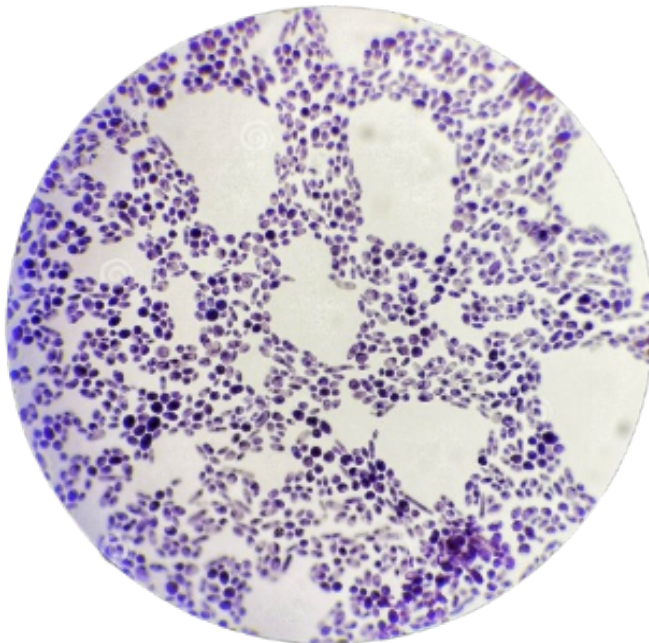


*Aspergillus flavus* on PDA agar    *Penicillium chrysogenum* on PDA

## SACCHAROMYCES CEREVISIAE (Brewer's Yeast)

### TAXONOMY OF SACCHAROMYCES CEREVISIAE (Brewer's Yeast)

**Taxonomy** is the scientific system of classifying organisms based on shared characteristics and evolutionary relationships. The *saccharomyces cerevisiae*, also called brewer's yeast or baker's yeast, is a species of yeast (single-celled fungal microorganisms). The species has been instrumental in winemaking, baking, and brewing since ancient times. It is believed to have been originally isolated from the skin of grapes. **Understanding their classification helps microbiologists identify and compare these organisms with other protists and microorganisms (Tortora, Funke and Case, 2019,p,579. Kathleen Park Talaro, 2005,p,579).**



*Figure 1.* Microscope image of *saccharomyces cerevisiae* (commonly brewer's yeast)

**Classification of *S. cerevisiae*:**

Rank	Name	Key Characteristics
Kingdom	Fungi	Heterotrophic eukaryotes with chitinous cell walls; they absorb nutrients rather than photosynthesizing
Phylum	Ascomycota	Commonly known as the sac fungi; they produce spores (ascospores) in a specialized microscopic sac called an <b>ascus</b>
Class	Saccharomycetes	Primarily unicellular fungi that lack a complex fruiting body (like a mushroom) and reproduce via budding



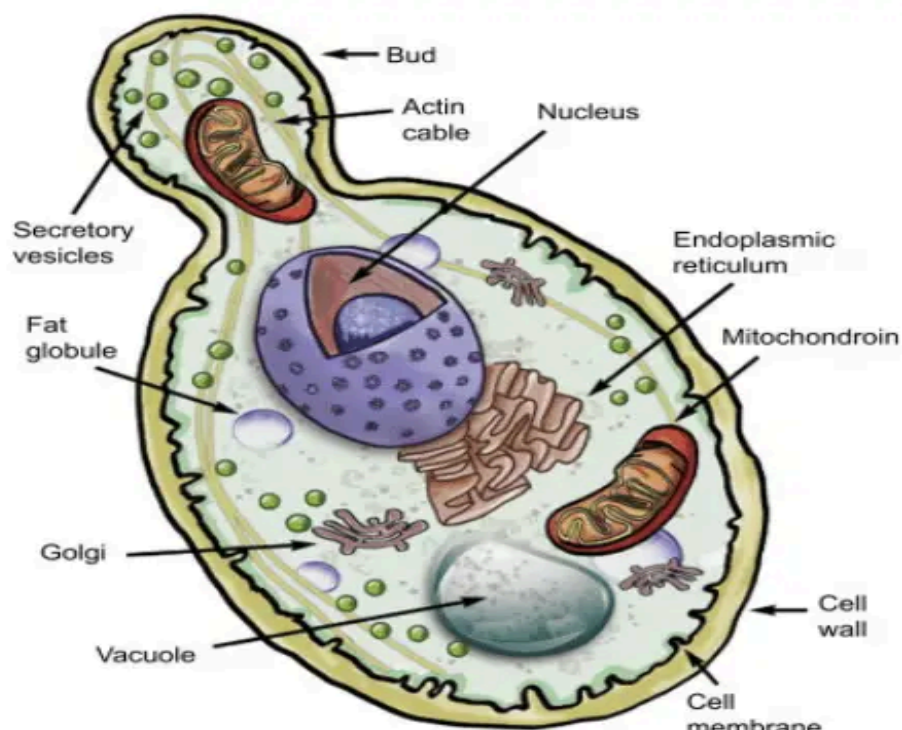
Order	Saccharomycetales	Known as the true yeasts; they are characterized by a predominant yeast phase and a lack of ballistoconidia
Family	Saccharomycetaceae	Typically fermentative yeasts that can convert sugars into ethanol and $\text{CO}_2$
Genus	Saccharomyces	Sugar fungus; fast-growing, sugar-loving yeasts that are highly tolerant to acidic environments and ethanol
Species	<i>S. cerevisiae</i>	Beer yeast; known for its ability to ferment hexose sugars and its use in baking, brewing, and as a model organism

### Additional information:

Other names and common names for the organisms are:

- Brewer's yeast, though other species are also used in brewing. Baker's yeast, Ale yeast, Top-fermenting yeast, Ragi yeast, Budding yeast, in connection to making tapai.
- This species is also the main source of nutritional yeast and yeast extract (Tortora, Funke and Case, 2019,p,579. Kathleen Park Talaro, 2005,p,579).

### MORPHOLOGY OF SACCHAROMYCES CEREVISIAE



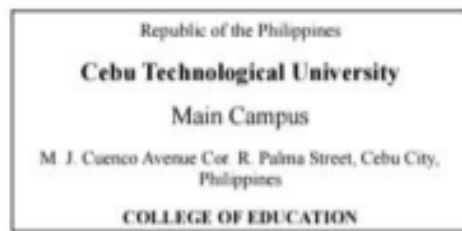


Figure 2. Labeled structure of *Saccharomyces Cerevisiae*

*Saccharomyces* is a genus of fungi that includes many species of yeasts. The name *Saccharomyces* is from Greek (sugar) and (fungus) and means sugar fungus. Many members of this genus are considered very important in food production where they are known as brewer's yeast, baker's yeast and sourdough starter among others. They are unicellular and saprotrophic fungi. One example is *Saccharomyces cerevisiae*, which is used in making bread, wine, and beer, and for human and animal health. *Saccharomyces* grow rapidly and mature in three days. They are flat, smooth, moist, glistening or dull, and cream in color. The inability to use nitrate and ability to ferment various carbohydrates are typical characteristics of *Saccharomyces*. Other members of this genus include the wild yeast *Saccharomyces paradoxus* that is the closest relative to *S. cerevisiae*, *Saccharomyces bayanus*, used in making wine, and *Saccharomyces cerevisiae* var. *boulardii*, used in medicine (Tortora et.al, 2019,p.579, Kathleen Park Talaro, 2005,p.579).

Morphology describes the structures of *S. cerevisiae*, while the next section explains how these structures function to support survival and reproduction.

## ANATOMY AND PHYSIOLOGY

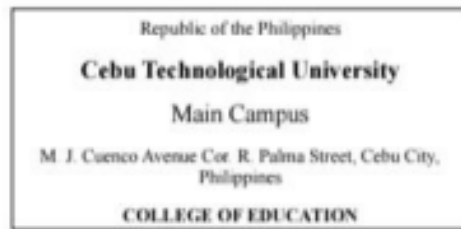
### *Saccharomyces cerevisiae* - ANATOMY (Structure)

*Saccharomyces cerevisiae* is a unicellular eukaryotic fungus . This means it has a true nucleus and membrane-bound organelles.

#### 1. Cell Wall

- Made mainly of glucans and mannoproteins
- Gives shape and protection
- Rigid but flexible

#### 2. Cell Membrane



- Controls movement of substances in and out
- Contains sterols (like ergosterol)

### 3. Nucleus

- Contains DNA
- Controls cell activities

### 4. Cytoplasm

- Jelly-like fluid where reactions occur

### 5. Vacuole

- Storage of nutrients and waste
- Maintains internal pressure

### 6. Mitochondria

- Site of cellular respiration
- Produces ATP (energy)

### 7. Bud Scar

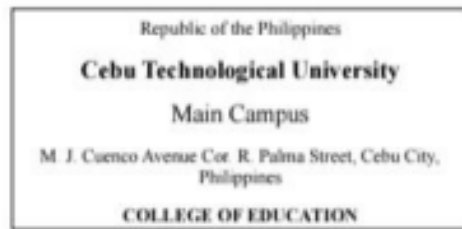
- Mark left after reproduction by budding
- 
- **PHYSIOLOGY (Functions)**

### 1. Reproduction

- Mainly reproduces by budding
- Can also reproduce sexually (forming spores)

### 2. Metabolism

- Performs aerobic respiration (with oxygen)
- Performs fermentation (without oxygen)
- Converts glucose → ethanol + carbon dioxide



- Important in bread, beer, and wine production

### 3. Growth Conditions

- Optimal temperature: 30°C
- Grows well in sugar-rich environments
- Can survive mild acidic conditions

### 4. Energy Production

- Uses glucose as primary energy source
- Produces ATP for growth and reproduction

### Importance

- Used in baking (CO<sub>2</sub> makes dough rise)
- Used in brewing and winemaking
- Model organism in genetics and molecular biology research

### Diseases with treatment and benefits

#### 1. Saccharomyces Infection (Saccharomycosis)

- Can affect the bloodstream, lungs, or urinary tract.
- More common in hospitalized or immunocompromised patients.

#### 2. Fungemia (Yeast in the Blood)

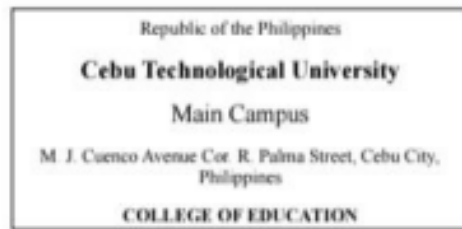
- Occurs when yeast enters the bloodstream.
- May cause fever and systemic infection.

#### 3. Allergic Reaction

- Some people may experience allergies from yeast exposure.

### TREATMENT

Treatment depends on severity:



## 1. Antifungal Medications

- Doctors may prescribe antifungal drugs such as fluconazole or amphotericin B.

## 2. Remove Source of Infection

- If infection is linked to medical devices (like catheters), they may be removed.

## 3. Supportive Care

- Monitoring and managing symptoms in hospital settings.

## BENEFITS OF *Saccharomyces cerevisiae*

Despite rare infections, it is highly beneficial:

### 1. Bread Making

- Produces carbon dioxide during fermentation, making dough rise.

### 2. Beer and Wine Production

- Converts sugar into alcohol and carbon dioxide.

### 3. Probiotic Use

- Certain strains help improve gut health and digestion.

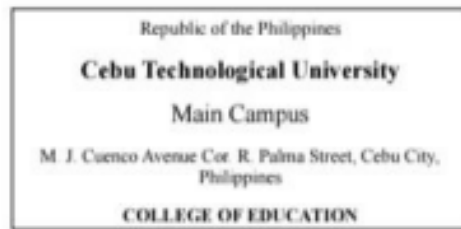
### 4. Research and Medicine

- Used as a model organism in genetics and biotechnology.
- Helps produce vaccines and recombinant proteins (like insulin).

### 5. Nutritional Supplement

- Rich in B vitamins, protein, and minerals.

**Other Possible Infections:**



## 1. Endocarditis

- Infection of the inner lining of the heart
- Very rare, usually in people with heart valve problems

## 2. Peritonitis

- Infection of the abdominal lining
- Reported in patients undergoing peritoneal dialysis

## 3. Pneumonia

- Lung infection
- Seen in severely immunocompromised patients

## 4. Urinary Tract Infection (UTI)

- Occurs when yeast grows in the urinary system

## 5. Skin or Wound Infection

- Can happen if yeast contaminates open wounds

### Important Note:

**Saccharomyces cerevisiae** is generally safe and is classified as a low-risk organism.

### Most infections occur in:

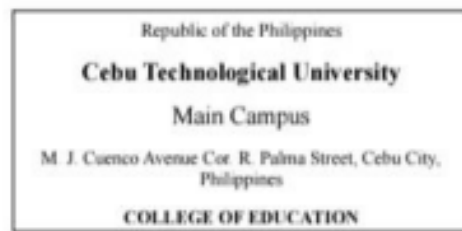
- People with weak immune systems
- Hospitalized patients
- Those using probiotic yeast supplements with medical devices (like catheters)

**Healthy individuals rarely develop disease from this yeast.**

## TECHNOLOGY AND LATEST DISCOVERIES OF *Saccharomyces cerevisiae*

### 1. Genetic Engineering & CRISPR Technology

- **Scientists modify yeast DNA using CRISPR.**
- **Used to study gene function.**



- **Helps produce medicines like insulin and vaccines.**

## **2. Recombinant Protein Production**

- **Yeast is engineered to produce:**
  - **Insulin**
  - **Hepatitis B vaccine**
  - **Human growth hormones**

## **3. Biofuel Production**

- **Modified yeast can convert plant sugars into ethanol.**
- **Helps create renewable energy sources.**

## **4. Synthetic Biology**

- **Scientists redesign yeast cells to:**
  - **Produce medicines**
  - **Create biodegradable plastics**
  - **Produce vitamins and enzymes**

## **5. Industrial Fermentation Technology**

- **Used in large bioreactors for:**
  - **Bread production**
  - **Beer and wine**
  - **Enzyme manufacturing**

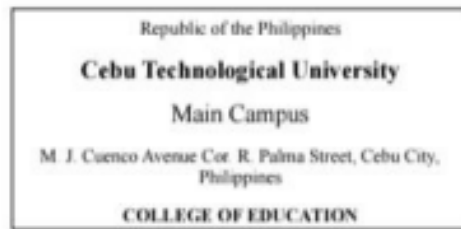
## **LATEST DISCOVERIES**

### **1. Synthetic Yeast Genome Project (Sc2.0)**

- **Scientists are building the first fully synthetic yeast genome.**
- **Helps understand how genes work.**
- **Allows custom-designed organisms.**

### **2. Cancer Research Applications**

- **Yeast is used to study cell division and DNA repair.**



- Helps understand how cancer develops.

### **3. Aging Research**

- Studies show yeast aging is similar to human cell aging.
- Helps researchers explore anti-aging treatments.

### **4. Stress Tolerance Engineering**

- New strains are developed to survive high temperature and alcohol levels.
- Improves biofuel and alcohol production efficiency.

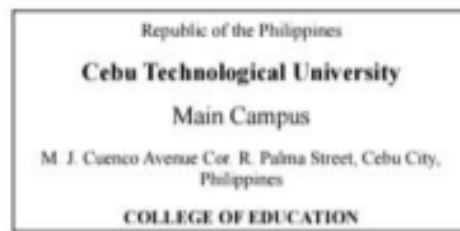
### **5. Space Research**

- Yeast is being studied for:
  - Survival in microgravity
  - Long-term space missions
  - Sustainable food production in space

#### **Why It Is Important Today:**

**Saccharomyces cerevisiae is one of the most studied organisms in biology**

- **A model organism in genetics**
- **Essential in medicine, food, and biotechnology**



## Agaricus Bisporus (Button Mushroom)

### Agaricus Bisporus

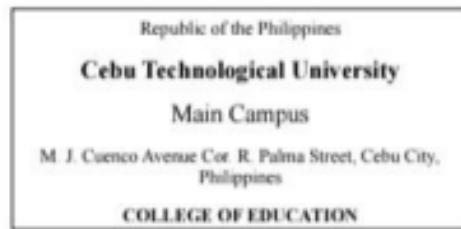
Agaricus bisporus, often seen in grocery stores, is the most familiar mushroom variety.

While it originates in wild fields, it is now predominantly cultivated in controlled environments to meet commercial demands. Its life cycle starts from a minute spore evolving into a visible mycelium, capable of generating additional spores, thus continuing the species growth. This cycle repeats across generations, forming a continuous process of growth and reproduction. This variety of mushroom is a popular choice as a pizza topping. It comes in different forms, including the larger portobello version, the brown variation and the smaller button version.

### Taxonomy of the Organism

- **Scientific Name:** *Agaricus bisporus*
- **Common Names:** Button mushroom, white mushroom, cremini, portobello
- **Kingdom:** Fungi
- **Phylum:** Basidiomycota
- **Class:** Agaricomycetes
- **Order:** Agaricales
- **Family:** Agaricaceae
- **Genus:** Agaricus
- **Species:** bisporus





*Agaricus bisporus* is one of the most widely cultivated and consumed edible mushrooms in the world. It originated in grasslands of Europe and North America but is now commercially grown globally.

### Morphology / Characteristics

- **Appearance:** Initially smooth and white, the cap flattens and turns brown with age. The underside has dark gills where spores are produced.
- **Size:** Cap size ranges from 1–4 inches in diameter.
- **Habitat:** Found in grassy areas in the wild or cultivated in composted soil in controlled environments.
- **Lifecycle:** Starts from spore germination, progresses through mycelium formation, and ends with fruiting body development.
- **Nutritional Value:** Low in calories, rich in protein, fiber, B vitamins, and minerals like potassium and selenium.
- **Culinary Uses:** Versatile in cooking—can be eaten raw or cooked in salads, soups, stir-fries, and sauces.
- **Health Benefits:** Supports immune function, aids digestion, and offers anti-inflammatory and antioxidant effects.
- **Commercial Cultivation:** One of the most widely cultivated mushrooms due to its popularity and ease of farming.
- **Varieties:** Includes white button, crimini, and portobello mushrooms, which are different maturity stages of the same species.
- **Environmental Impact:** Recycling agricultural waste for compost supports sustainable farming practices.

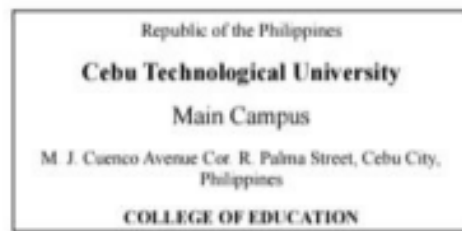
### Anatomy and Physiology

#### Vegetative Structure

- **Mycelium:** A network of hyphae that spreads through the substrate, absorbing nutrients for growth. It forms the vegetative part of the mushroom and is typically hidden underground.

#### Primary Mycelium

- **Monokaryotic:** Formed when basidiospores germinate and produce single-nucleated cells. This phase is short-lived as the cells soon fuse.



## Secondary Mycelium

- Dikaryotic: Formed when compatible hyphae from two strains fuse, resulting in binucleate cells. This phase is more stable and continues to grow, forming the foundation for fruiting.

## Tertiary Mycelium

- Fruiting Body Formation: This mycelium extends underground and forms specialized tissue that develops into the visible fruiting body (the mushroom). The hyphae here remain septate (with partitions) and are responsible for producing the mature mushroom.

## Fruiting Body or Basidiocarp

- Mushroom Structure: The fruiting body is the reproductive part of the fungus. It consists of tightly packed hyphae, forming the cap, gills, and stem. Spores are produced on the gills.

## Structural Features of *Agaricus bisporus*

### Cap (Pileus)

- The top, umbrella-like part of the mushroom, varies in shape, size, and color. It protects the gills beneath it and changes as the mushroom matures.

### Gills

- Located under the cap, these thin radiating structures produce spores. They start as white, then turn pink, and eventually brown as the spores mature.

### Stem (Stipe)

- The cylindrical structure supporting the cap, connecting it to the substrate. It varies in length, thickness, and texture.

### Ring (Annulus)

- A fibrous ring found on the stem, left behind by the partial veil as the mushroom matures. Its size and texture vary by species.

### Volva

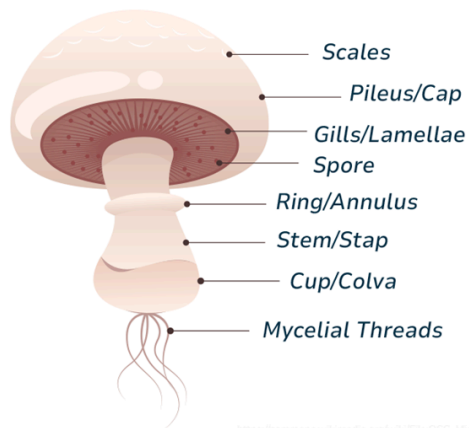


- A cup-like structure at the base of the stem, formed from the remnants of the universal veil. Not always present, but useful for identification.

### Spores

- Microscopic, reproductive structures produced on the gills. Spores are released into the environment and vary in color, shape, and size, helping in species identification.

## Agaricus Bisporus



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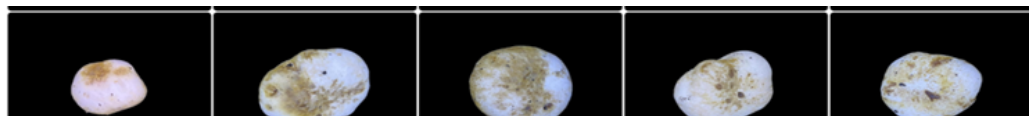
### Diseases and Benefits

The economic production of *Agaricus bisporus* is subject to various diseases that impact yield and quality:

#### 1. Bacterial Blotch

- **Cause:** *Pseudomonas* species.
- **Impact:** Leads to discoloration and blemishes on the caps, reducing marketability.

#### Bacterial Blotch





### Symptoms:

**Brown Discoloration** - Dark discoloration symptoms of brown blotch seen on brown strains of mushrooms.

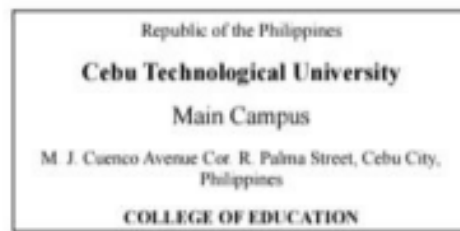


**Ginger Blotch** - Ginger blotch symptoms typically have a lighter, ginger-coloured appearance, with lesions showing no or only mild sunken appearance.



**Pseudomonas costantinii** - It causes speckling or pitting on mushroom caps, and brown discoloration, often where mushrooms are touching each other.





### Treatment:

- Adding sodium hypochlorite with 150 ppm chlorine to the water used for watering the crops can help control blotch, as long as the mushrooms are kept dry.

### 2. Green Mold Disease

- **Cause:** *Trichoderma* species.
- **Impact:** Fungal contamination that competes with the mushroom, damaging crops and reducing yield.



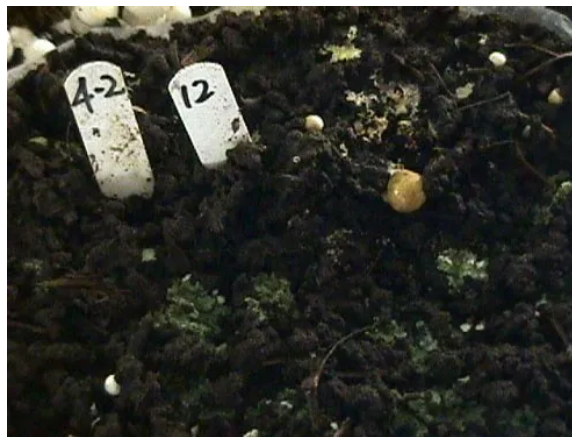
### Symptoms:

- The pathogenic fungus appears to gain entry to growing rooms primarily through contaminated personnel and equipment.



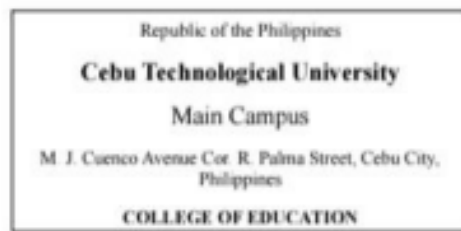


- Small pins turn brown and appear to lytically degrade.



- The bag on the left shows casing with healthy spawn growth, while the bag on the right shows the effects of green mold caused by *Trichoderma harzianum* biotype 4





### Treatment/Prevention:

- Clean up mold immediately.
- Rigorous hygiene with 2% formalin
- Chemical control using fungicides like carbendazim (0.1%), thiophanate-methyl, or prochloraz-manganese (0.1–0.2%) applied to casing soil.

### 3. Dry Bubble Disease

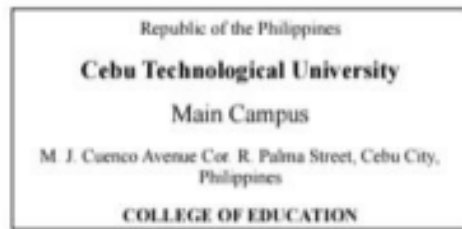
- **Cause:** *Verticillium fungicola*.
- **Impact:** Affects the development of fruiting bodies, causing deformed mushrooms, which lowers crop value.

**Symptoms: Bubble** - The most conspicuous symptom found is described as a globe-like mass of mushroom tissue.



**Split Spite** - When infection takes place after the pin begins to develop and the stem is infected, the stem splits as it matures, causing a symptom described as split stipe or stem blowout.





**Necrotic Spots** - This symptom is described as large brown spots with a fuzzy grayish hue in the center. These spots are usually the diameter of a pencil eraser head to a dime size.



**Spotting** - A needle pinhead-sized brown spotting of the mushroom cap is another symptom.

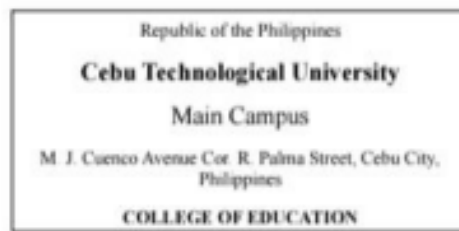


**Treatment:**

- Treatment with 1.25 % 1-octen3-ol also known as mushroom alcohol in water reduced the number of mushrooms with symptoms of dry bubble disease after 3 flushes significantly.

**4. Cobweb Disease** - A fungal disease that often infects farmed edible mushrooms, causing big crop damage and financial loss.

- **Cause:** *Cladobotryum dendroides*



- **Impact:** It caused very serious money loss, with crop production sometimes dropping by more than 40% because the disease spreads fast and makes the plants die early.

### Symptoms:

The primary symptom of Cobweb disease is circular patches of cottony white cobweb-like mycelium growing over casing soil and mushrooms. It can also cause yellowing, pink-tinged discoloration and irregular brown spotting (either on the bed or post-harvest).



### Treatment:

- Salt Application , where treating disease by covering with salt has also been shown to be effective in causing the Cladobotryum spores to become airborne so great care must be taken to prevent this happening.

### Health Benefits of Agaricus bisporus

The health benefits of *Agaricus bisporus* also contribute to its economic importance, especially as a dietary and medicinal component:

#### 1. Nutrient-Rich

- **Low-Calorie:** Ideal for weight management.
- **Rich in Vitamins and Minerals:** Includes B vitamins (e.g., riboflavin, niacin, pantothenic acid) and essential minerals like potassium and selenium





### 3. Digestive Health

- High in fiber, supporting digestive function and gut health.

### 4. Potential Antioxidant and Anti-Cancer Properties

- Contains ergothioneine and glutathione, antioxidants that protect cells from damage and may have cancer-fighting properties.

### 5. Low in Fat

- Makes it a heart-healthy food option, suitable for low-fat diets

## Economic Benefits Related to Cultivation

The following are economic advantages that stem from *Agaricus bisporus* cultivation:

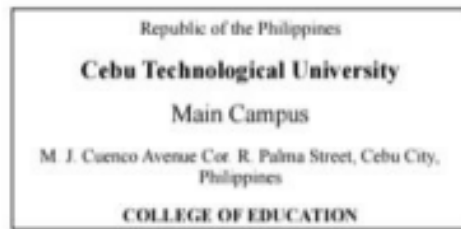
- **Job Creation:** Cultivation and distribution create jobs in agriculture, food processing, and retail, contributing to local economies.
- **Sustainable Practices:** Using agricultural waste (e.g., wheat straw, corn cobs) for substrate reduces environmental impact and promotes recycling.
- **Demand in Global Food Industry:** Its widespread use in diverse cuisines boosts demand, driving continued cultivation.
- **Research and Innovation:** Ongoing studies into cultivation methods and medicinal properties drive agricultural and biotechnology innovation, further boosting the mushroom's economic value.

## Latest Technology / Treatment / New Discovery / Updated Research

Recent research and technological advancements involving *Agaricus bisporus* include:

### 1. Sustainable Cultivation Technology

Modern mushroom farms use:



- Climate-controlled growing rooms
  - Automated humidity and CO<sub>2</sub> control systems
  - Compost recycling systems
- These innovations increase yield and reduce environmental impact.

## 2. Genetic Research

Genome sequencing of *Agaricus bisporus* has improved understanding of:

- Disease resistance
- Yield improvement
- Environmental adaptability

This supports selective breeding programs.

## 3. Medical Research

Recent studies are investigating:

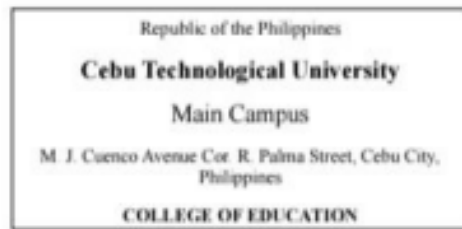
- Anti-cancer properties of mushroom extracts
- Immune-modulating compounds
- Role in reducing inflammation

Research continues to explore bioactive compounds such as beta-glucans.

## 4. Alternative Protein & Sustainability

As global demand for sustainable food increases, *Agaricus bisporus* is being studied as:

- A meat substitute
- A source of sustainable protein
- A contributor to circular agriculture systems



# Penicillium Chrysogenum (Penicillin-producing mold)

## Introduction

*Penicillium chrysogenum* is a widely studied species of *Penicillium*, sometimes known as *P. notatum*, though these names are not always synonymous. It is medically important because it produces penicillin, an antibiotic that inhibits the formation of bacterial cell walls, leading to cell lysis. In addition to its role in medicine, it can act as a pathogen or allergen and may also help protect crops from certain diseases. The genus was first discovered by Alexander Fleming, who observed that a contaminating mold caused *Staphylococcus* cultures to lyse; he described the mold as starting as a white fluffy mass that later turns green and black with a yellow pigment diffusing into the medium. *P. chrysogenum* is commonly found in moist, nutrient-rich soils but can also inhabit forest soils, bee provisions, Arctic ice, and fruits, where it may cause decay.

## Taxonomy of the Organism

*Penicillium chrysogenum* is a filamentous, saprophytic fungus belonging to the kingdom Fungi, phylum Ascomycota, and is widely known as a producer of penicillin. It is characterized as a blue-green, fast-growing mold commonly found in indoor environments, soil, and on decaying organic matter.

## Taxonomic Hierarchy

**Scientific name:** *Penicillium chrysogenum*

**Common name:** Penicillin mold

**Domain:** Eukaryota

**Kingdom:** Fungi

**Phylum:** Ascomycota

**Class:** Eurotiomycetes

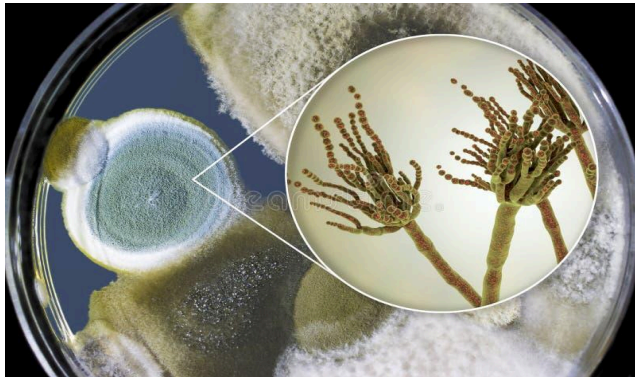
**Order:** Eurotiales



**Family:** Aspergillaceae (formerly Trichocomaceae)

**Genus:** *Penicillium*

**Species:** *Penicillium chrysogenum*



*Penicillium chrysogenum* is often found in damp indoor environments and produces other compounds besides penicillin, such as roquefortine C and meleagrins

## Morphology/Characteristics

- **Colony Appearance:** Starts as white, fluffy mass, maturing into a velvet-like texture with a blue-green color and a white edge
- **Pigmentation:** Often produces a yellowish pigment that diffuses into the growth medium.
- **Microscopic Features:** Features branched, septate hyphae (network of threads)
- **Reproductive Structure:** Produces characteristic brush-shaped structures called conidiophores (specifically *penicilli*) that bear conidia (spores)
- **Conidia:** Spherical, dry, and produced in chains allowing for easy dispersal by air.
- **Habitat and Ecology:** Ubiquitous in nature commonly found in soil, decaying organic matter, and damp indoor environment
- **Metabolism and Growth**
  - **Antibiotic Productions** - Famous for the commercial production of penicillin, as well as other metabolites like xanthocillin
  - **Metabolic By-products** - Produces acids such as oxalic, citric, and gluconic acids
  - **Adaptability** - Thrives in diverse environment



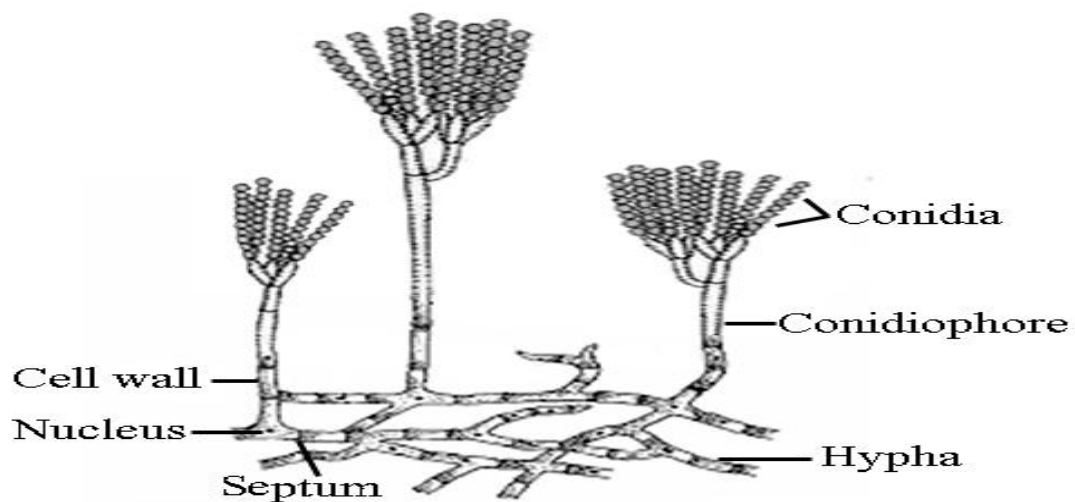
- **Reproduction:** Primarily reproduces asexually through conidia
- **Health Impact:** Generally safe, but can cause opportunistic infections in severely immunocompromised individual

## Anatomy and Physiology

### Anatomy

Understanding the structural organization of *Penicillium chrysogenum* is essential in explaining how it grows, reproduces, and adapts to different environments. As a filamentous eukaryotic fungus, its body is composed of specialized microscopic structures that work together to support nutrient absorption, reproduction, and cellular activity. Its anatomy can be examined at different levels, including the vegetative structures, reproductive components, and subcellular features, each contributing to its overall biological function and development.

### Vegetative Anatomy



**Fig: *Penicillium spp.*** Mycellium showing hyphae and conidiophores bearing conidia.

- **Mycelium** – The vegetative body of the fungus. It is well-developed, freely branched, and forms the main structure that supports growth. Mycelium is

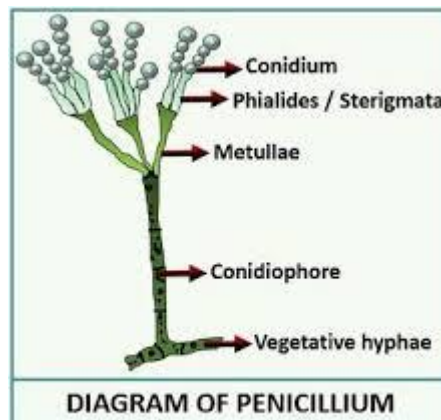


composed of networks of hyphae that spread in all directions on the substratum. In some species, it can form compact structures called sclerotia.

- **Hyphae** – Slender, tubular, colorless thread-like structures that make up the mycelium. They are septate (divided by cross walls) and branch repeatedly.
- **Substratum hyphae** – Hyphae that grow along or penetrate the surface. Some ramify superficially on the substratum while others penetrate to produce rhizoids, which absorb nutrients.
- **Aerial hyphae** – Hyphae that grow above the substratum. These support the formation of conidiophores, which are the fruiting bodies responsible for asexual reproduction.
- **Sclerotium** (optional in some species) – A compact, hardened mass of mycelium that helps the fungus survive unfavorable conditions.

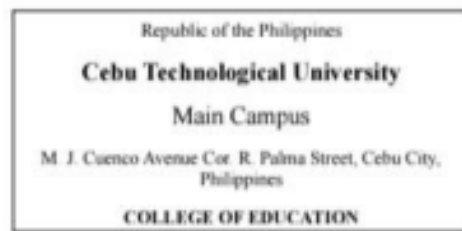
### Reproductive Anatomy (Asexual- “Brush” Structure)

The name *Penicillium chrysogenum* originates from the latin *penicillus* (painter's brush), describing the characteristics brush-like shape of its asexual reproductive structures.



BIOLOGY READER

- **Conidiophore:** The specialized, long, upright hyphae that bear asexual spores. These are typically terverticillate (branched in three levels) or quarterverticillate (four levels), extending up to 50  $\mu\text{m}$ . The stipes (stalks) can be smooth and rough-walled.
- **Metulae:** Branching structures arising from the conidiophores, which in turn bear phialides.
- **Phialides:** Flask-shaped cells arising in groups (verticils) from the metulae, which produce conidia (spores)



- **Conidia (Spores):** Asexual spores produced in basipetal succession (youngest at the base) in long, dry, chains. They are typically smooth, globose, or ellipsoidal, measuring roughly 3.0-4.0  $\mu\text{m}$  in diameter. These are dispersed by wind

### Sexual Anatomy and Cycle

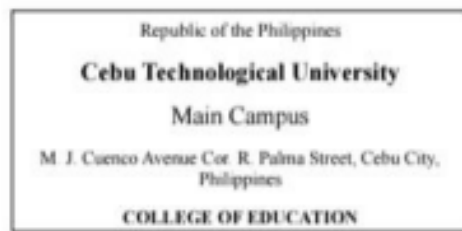
- **Sexual State (Teleomorph):** The sexual stage involves the formation of cleistothecia. These are closed, spherical, ascocarp structures that contain asci.
- **Sexual Organs:** The female sex organ is the ascogonium, and the male sex organ is the antheridium. The antheridium coils around the ascogonium, and following fusion (plasmogamy), they undergo meiosis.
- **Ascospores:** Within the cleistothecia, asci are formed, which produce eight distinct, haploid ascospores. These are sexual spores, in contrast to the commonly produced asexual conidia.
- **Mating Type Genes:** The sexual cycle is controlled by mating-type (MAT) genes, specifically *mat1-1-1* (encoding an alpha-box domain protein) and *mat1-2-1* (encoding an HMG-domain protein).

### Subcellular Anatomy (Industrial Relevance)

- **Peroxisomes:** A critical site for the biosynthesis of penicillin (specifically the enzyme isopenicillin N acyltransferase).
- **Nucleus:** Multinucleate hyphae allow for high metabolic activity and rapid growth.
- **Mitochondria:** Thread-like mitochondria are present, and their metabolism is often studied in relation to antibiotic production.

### Physiology

The physiology of *Penicillium chrysogenum* describe the essential biological functions that allow this fungus to grow, survive, and produce important metabolites such as penicillin. As a common saprophytic mold found in soil and decaying organic matter, it exhibits a combination of structural, metabolic, and ecological traits that support its adaptation to diverse environments. These include its characteristic hyphal organization, efficient mechanism for nutrient acquisition, well-developed metabolic pathways, and highly regulated systems for asexual reproduction and secondary



metabolite production. Understanding the physiology of *P. chrysogenum* provides the foundation for analyzing its morphology, growth requirement, nutrient utilization, metabolic activities, and responses to environment conditions. Each of these components contributes to the organism's natural ecological role as well as its industrial value in antibiotic production.

## 1. Structural Morphology

As a filamentous fungus, its physical makeup is designed for expansion and nutrients absorption.

- **Hyphae:** The body consists of a network of thread-like structures called hyphae. These grow at the tips (apical growth) and form a dense mat known as mycelium.
- **Cell wall:** Composed primarily of chitin and glucans, providing structural integrity and protection against osmotic pressure.
- **Conidiophores:** These are specialized “brush-like” structures used for asexual reproduction. They produce chains of spores called conidia, which give the fungus its characteristic blue-green color.
- **Septation:** The hyphae are separate, meaning they have cross-walls with pores that allow cytoplasm and even organelles to flow between “cells”.

## 2. Metabolism and Penicillin Production

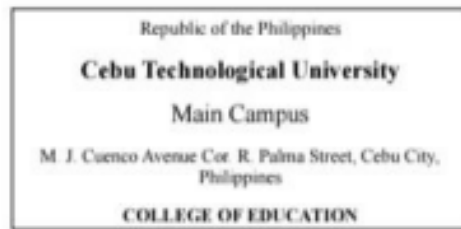
The “star of the show” is its secondary metabolism - specifically how it creates the antibiotic.

- **Primary vs. Secondary Metabolism:** \* **Primary:** Focuses on growth and energy (glycolysis, TCA cycle).
- **Secondary:** This is where Penicillin G or V is produced. It usually happens during the idiophase (the period after active growth slows down).
- **Biosynthesis Pathway:** It synthesizes penicillin from three specific amino acids: L- $\alpha$ -aminoadipic acid, L-cysteine, and L-valine.
- **Enzymatic Catalysis:** The process is driven by key enzymes like ACV synthetase. In industrial settings, precursors like phenylacetic acid are added to “force” the fungus to produce specific types of penicillin.

## 3. Growth Physiology (The “Living” Requirements)

For this fungus to thrive (and produce medicine), its environment must be precisely tuned:

- **Carbon Source:**



Prefers glucose for growth, but lactose is often used in industry because it's a "slow-burn" sugar that favors penicillin production.

- **Nitrogen Source:**  
Utilize ammonium salts, corn steep liquor, or yeast extract.
- **Temperature:**  
Optimal growth occurs between 23°C and 28°C.
- **pH Levels:**  
Needs a slightly acidic to neutral environment, typically maintained around pH 6.5 for maximum antibiotic yield.
- **Oxygen:**  
It is an obligate aerobe, meaning it requires high levels of dissolved oxygen. This is why industrial fermenters use massive agitators to stir the "broth".

## Diseases and Benefits

Often called a "vintage model with a cutting-edge profile," *Penicillium chrysogenum* (recently reclassified as *P. rubens*) occupies a unique dual role in human history.

On one hand, it is a biotechnological powerhouse responsible for the dawn of the antibiotic era, saving millions of lives through the production of penicillin. On the other, it is a ubiquitous environmental mold that can act as a persistent indoor allergen and, in rare cases, an opportunistic pathogen.

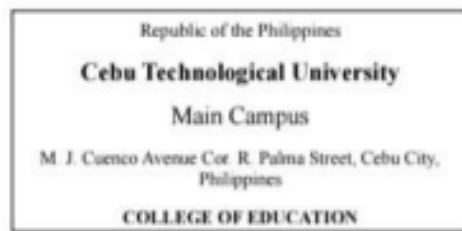
Understanding its impact requires balancing its monumental medical benefits against the respiratory and clinical challenges it poses to human health.

## Benefits of *P. chrysogenum*

While *Penicillium chrysogenum* is synonymous with the antibiotic revolution, its modern-day benefits extend far beyond the pharmacy shelf into agriculture, industry, and environmental science.

### 1. Pharmaceutical & Medical Benefits

This fungus remains one of the most important "cell factories" in medical history.



- **Mass Production of Natural Penicillins:** It is the primary industrial source for Penicillin G and V, used to treat infections like syphilis, meningitis, and pneumonia.
- **Source of Semi-Synthetic Antibiotics:** It produces the core molecule 6-APA (6-aminopenicillanic acid), which scientists use to build modern drugs like Amoxicillin and Ampicillin.
- **Anti-HIV Potential:** Recent studies (2023–2025) show that certain metabolites, such as xanthoviridicatin, can inhibit the HIV-1 integrase enzyme, offering new paths for antiviral research.
- **Novel Antibacterials:** Researchers are exploring compounds like **Chrysogenotoxin**, which show activity against antibiotic-resistant pathogens like *S. pneumoniae*.

## 2. Industrial & Biotechnological Benefits

Industries use the fungus for its powerful ability to produce enzymes and break down complex materials.

- **Enzyme Production:** It is an industrial source for Glucose Oxidase (used in food preservation and biosensors) and Polyamine Oxidase.
- **Biocatalysis:** It is used to produce organic acids and specialized pigments that are eco-friendly alternatives to synthetic dyes.
- **Pulp and Paper Industry:** *P. chrysogenum* is used to treat pulp mill waste, helping to break down lignin and other tough plant materials.

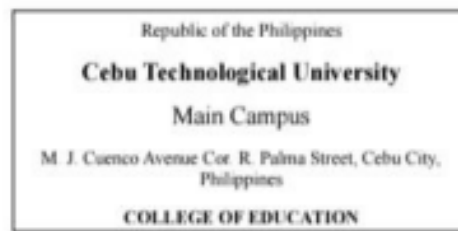
## 3. Agricultural & Environmental Benefits

The fungus is a silent worker in the soil and a protector of crops.

- **Plant-Growth Promotion:** As a PGPF (Plant-Growth-Promoting Fungus), it lives near plant roots and helps them absorb minerals like phosphorus more effectively.
- **Biocontrol Agent:** It produces antifungal proteins (like PAF) that protect crops (apples, grapes, tomatoes) from harmful pathogens without the need for chemical pesticides.
- **Bioremediation (Metal Cleanup):** It is a "hyper-accumulator" of heavy metals. It can absorb and detoxify Lead (Pb) and Cadmium (Cd) from contaminated soil and water.

## “Diseases” and Health Risks

Based on medical literature, clinical case reports, and mycological databases, here is a consolidated list of all diseases and health conditions associated with *Penicillium chrysogenum* (also known as *P. rubens*).



They are categorized by how they affect the human body, ranging from common environmental reactions to rare, life-threatening infections.

## 1. Respiratory & Allergic Diseases

These are the most common conditions, typically caused by inhaling airborne spores in damp or moldy buildings.

- **Type I Allergic Reactions:** Includes allergic rhinitis (hay fever), sneezing, and skin rashes (eczema).
- **Bronchial Asthma:** *P. chrysogenum* is a major "trigger" fungus that causes airway constriction and distress in asthmatic individuals.
- **Hypersensitivity Pneumonitis (HP):** Also called "Extrinsic Allergic Alveolitis." A serious lung inflammation caused by long-term inhalation of mold spores.
- **Allergic Bronchopulmonary Penicilliosis (ABPP):** Similar to aspergillosis, where the fungus colonizes the airways and triggers a persistent immune overreaction.

## 2. Deep-Tissue & Systemic Infections (Mycoses)

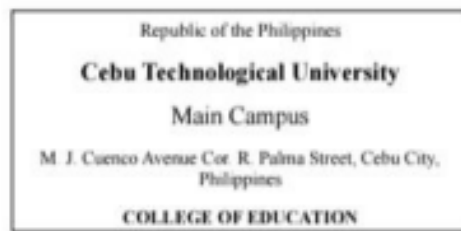
These generally occur in immunocompromised patients (e.g., those with HIV/AIDS, cancer, or organ transplants).

- **Necrotizing Pneumonia:** A severe infection where the fungus causes the death (necrosis) of lung tissue.
- **Fungemia:** The presence of the fungus in the bloodstream, which can lead to septic shock.
- **Disseminated Penicilliosis:** A "whole-body" infection where the fungus spreads to the liver, spleen, and lymph nodes.
- **Endocarditis:** Infection of the heart's inner lining or heart valves, usually following surgery or the use of prosthetic valves.
- **Necrotizing Esophagitis:** Severe inflammation and tissue death in the esophagus (throat).

## 3. Localized Infections

These occur when the fungus enters a specific "niche" or a break in the skin/mucosa.

- **Otomycosis:** Fungal infection of the external ear canal (causing pain and discharge).



- **Mycotic Keratitis:** Infection of the cornea of the eye, often following a physical injury to the eye.
- **Endophthalmitis:** Inflammation of the interior of the eyeball, which can lead to vision loss.
- **Cutaneous Mycosis:** Rare skin infections, usually appearing as nodules or ulcers in patients with suppressed immune systems.

#### 4. Toxin-Related Conditions (Mycotoxicosis)

These result from consuming food (grains, fruits, or meats) contaminated by the fungus.

- **Nephrotoxicity:** Kidney damage caused by the ingestion of mycotoxins like Citrinin or Ochratoxin A.
- **Neurotoxicity:** Tremors or neurological symptoms (primarily documented in animals) caused by the metabolite Roquefortine C.

Research on *Penicillium chrysogenum* (now also classified as *P. rubens*) has entered a "high-tech" era. In 2025 and 2026, the focus has shifted from just making penicillin to using the fungus as a **synthetic biology factory** and a source for next-generation medicine.

Here are the latest discoveries and research updates:

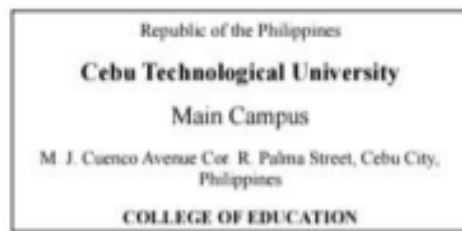
#### 1. New Medical Discoveries (Antibacterial Breakthroughs)

Researchers have moved beyond traditional penicillin to find "hidden" compounds within the fungus to fight superbugs.

- **Chrysogenotoxin & Penichrysogenone A (2025/2026):** Recent studies isolated these new metabolites. Chrysogenotoxin has shown potent activity against Gram-negative bacteria, which are notoriously difficult to kill.
- **NDM-1 Inhibitors:** A major discovery in 2025 identified compounds in Red Sea-derived *P. chrysogenum* that can inhibit NDM-1, an enzyme that makes bacteria resistant to almost all current antibiotics. This could "unlock" the power of old antibiotics again.
- **Antifungal Properties:** New natural products from the fungus, such as specific *indole diketopiperazines*, have shown effectiveness against *Candida auris*, a high-priority fungal threat identified by the WHO.

#### 2. Advanced Technology (The "Cell Factory")

We are no longer just "growing" the mold; we are "reprogramming" it.



- **CRISPR/Cas9 Multiplexing (2026):** New CRISPR toolkits now allow scientists to edit multiple genes at once in *P. chrysogenum*. This is being used to "silence" genes that produce toxins and "turn up" genes that produce medicine.
- **Peroxisome Engineering:** Recent research has mapped exactly how the fungus uses its internal "compartments" (peroxisomes) to build penicillin. By expanding these compartments, scientists are creating "Super-Strains" with 10x the production capacity.
- **Marine-Derived Strains:** Scientists are now harvesting *P. chrysogenum* from deep-sea corals and sponges. These "extremophile" versions have evolved different genes and produce entirely unique chemical structures not found in land-based versions.

### 3. Industrial & Food Science Updates

- **Flavor Engineering in Fermentation (2025):** New research into soybean fermentation has identified specific strains of *P. chrysogenum* that produce high levels of protease and lipase. This technology is being used to create "designer" fermented foods with enhanced umami flavors and better nutritional profiles.
- **Eco-Friendly "Bio-Mining":** 2024-2025 studies have optimized the fungus for bioremediation, specifically using it to "eat" heavy metals like Lead (Pb) and Zinc (Zn) from industrial wastewater, turning toxic sites into clean environments.

### 4. Updated Clinical Treatment (For Infections)

Since the WHO released a major report on fungal diseases in April 2025, treatment protocols have been updated:

- **Resistance Monitoring:** Because *P. chrysogenum* is becoming more resilient, doctors are moving away from standard fluconazole.
- **Current Gold Standard:** Treatment for rare systemic infections now focuses on Amphotericin B and Itraconazole, often combined with surgical removal of the fungal mass (fungus ball) if it is in the lungs.

## Conclusion

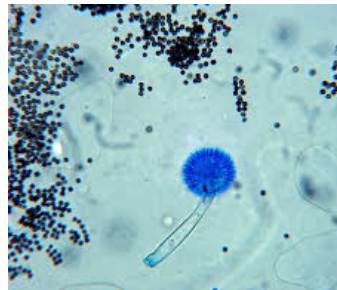
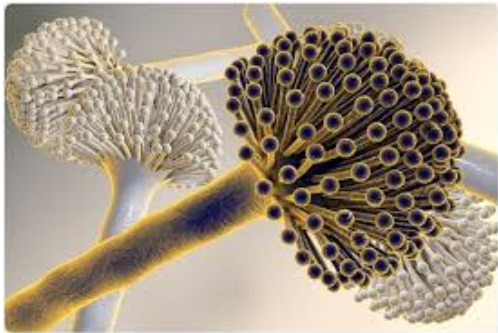
In conclusion, *Penicillium chrysogenum* is a biological powerhouse that bridges the gap between common environmental mold and life-saving medicine. While it is the primary source of penicillin and a versatile "cell factory" for modern biotechnology, it maintains a dual nature as a significant indoor allergen and a rare opportunistic pathogen. Today, cutting-edge research in CRISPR-Cas9 engineering is transforming this fungus into a precision tool for cleaning toxic environments and developing new weapons against antibiotic-resistant superbugs. Ultimately, it remains one of the most indispensable organisms in human history, evolving from a lucky discovery into a sophisticated partner in global health and sustainability.



## ASPERGILLUS NIGER ( Black Mold)

### INTRODUCTION

- **Aspergillus niger** stands out as the most prevalent species within the **Aspergillus** genus.
- Its name derives from the Latin word "**aspergillum**," meaning a holy water sprinkler, inspired by its distinctive sprinkler-like structure visible under a microscope.
- This fungus is commonly responsible for the formation of black mold on various fruits and vegetables, including grapes, apricots, onions, and peanuts.
- Additionally, *Aspergillus niger* is a frequent culprit behind food contamination and spoilage, impacting food quality and safety.



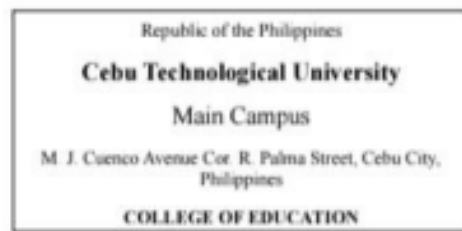
**Black mold disease**

**Images of  
Aspergillus niger  
disease in grapes  
and onion**



### Natural Environment of *Aspergillus Niger*

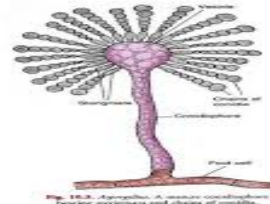
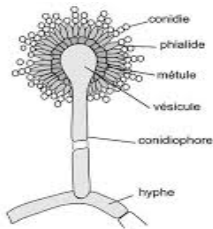
- **Aspergillus niger** exhibits remarkable heat tolerance, enabling it to survive and flourish across a wide temperature spectrum, from freezing cold to scorching heat.
- Its ability to reproduce asexually allows it to rapidly colonize diverse habitats whenever conditions become favorable, making it a highly opportunistic organism.



- This fungus predominantly inhabits decomposing plant matter such as compost heaps and fallen leaves, thrives in soil, and is commonly found contaminating stored grains, dried fruits, nuts, and even synthetic materials like polyester.

## Morphology of *Aspergillus Niger*

- ***Aspergillus niger*** is a filamentous fungus characterized by thread-like hyphae, giving it a plant-like appearance.
- When observed macroscopically, its colonies start off white but gradually darken to black over several days as they produce conidial spores. The colony margins display a pale yellow hue and develop radial cracks.
- Under the microscope, *Aspergillus niger* features smooth, pigmented conidiophores along with conidia, which are its asexual spores.



## CONT...

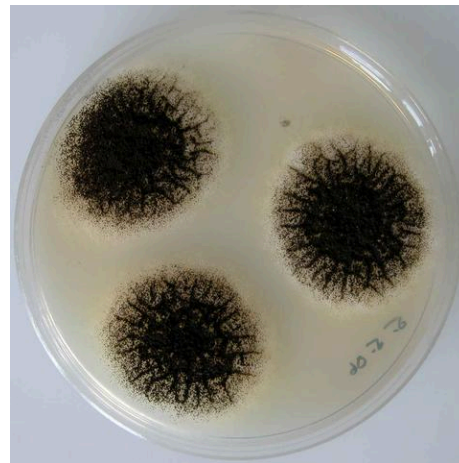
- **Conidiophores** range from 400 to 3000 micrometers in length, exhibiting a smooth and translucent appearance.
- Their tips darken, culminating in a spherical vesicle measuring between 30 and 75 micrometers in diameter.
- This vesicle is densely covered by metulae and phialides.
- The phialides generate conidia characterized by a coarse surface texture, a dark brown hue, and a size of 4 to 5 micrometers in diameter.

## Cultural Traits of *Aspergillus Niger*

- Colonies typically exhibit a fluffy, cotton-like texture, starting off white to yellow before maturing into a deep black shade. These structures consist of dense, felt-like conidiophores. The underside (reverse) of the colony shows hues ranging from white to yellow. Under the microscope, the conidial heads display a radiating pattern with biserial conidiogenous cells, and the spores (conidia) appear brown.

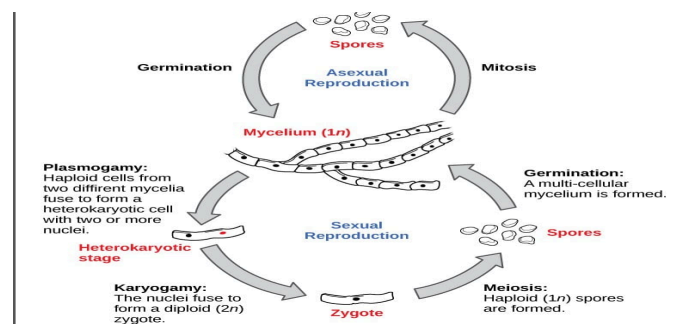


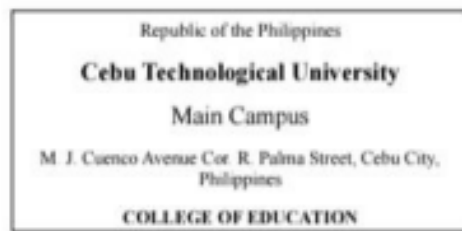
- When grown on potato dextrose agar at 25°C, the colonies begin as white but rapidly darken to black as conidia develop. The reverse side of the agar plate takes on a pale yellow color, and the colony's expansion may cause radial cracks to form in the medium.
- **Malt Extract Agar:** When incubated for 7 days at temperatures of 25°C and 37°C, this medium yields colonies that are lightly brown in color, featuring smooth walls on the conidia.
- **Czapek Yeast Agar:** After 5 days of incubation at both 25°C and 37°C, this agar produces black colonies characterized by a woolly texture and smooth-walled conidia.



### Aspergillus niger Life Cycle

- **Aspergillus niger** propagates through asexual reproduction by generating conidial spores.
- The cycle begins when these spores land on a surface that offers optimal conditions, typically between 25 and 40°C.
- Upon settling, the conidia germinate, giving rise to a vegetative cell.
- This cell then grows into a network of hyphal mycelium, which branches repeatedly in a dichotomous pattern, eventually producing aerial hyphae.





- The aerial hyphae extend upward, developing into conidiophores that expand at their tips to create a swollen structure called the vesicle.
- Emerging from these vesicles are the primary sterigmata, referred to as phialides.
- These primary sterigmata give rise to secondary sterigmata, which initiate the production of conidial spores.
- The spores are organized in multiple vertical rows, forming columns atop the phialides.

### Applications of *Aspergillus niger*

- ***Aspergillus niger*** is widely recognized for its ability to produce citric acid, a key ingredient extensively used as a preservative in canned fruits, dried nuts, and dried fruits.
- This fungus also generates **glycoside hydrolase enzymes**, which play a crucial role in converting plant biomass into biofuels by breaking down cellulose and hemicellulose into fermentable sugars for ethanol production.
- Additionally, *Aspergillus niger* serves as a valuable source for synthesizing bioactive compounds and various pharmaceutical substances.

### PATHOGENESIS OF ASPERGILLUS NIGER

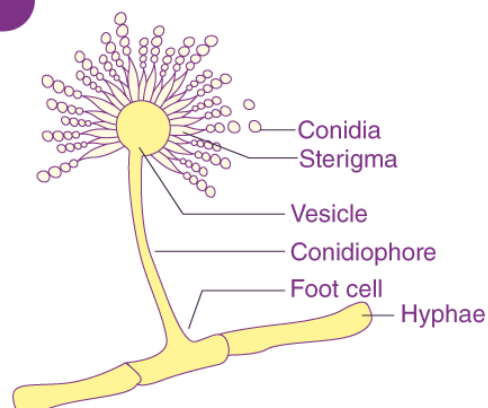
#### Plant manifestations

- ***Aspergillus niger*** causes a black mold of onions and ornamental plants by infecting onion seedlings. It can disseminate and become systemic and manifest when conditions are favorable.
- *A. niger* causes a common postharvest disease of onions, in which the black conidia can be observed between the scales of the bulb.
- It can also cause disease in peanuts and in grapes.

### ANATOMY STRUCTURE OF ASPERGILLUS NIGER

*Aspergillus* is a widespread fungus found almost anywhere (in the air, soil, water etc.).

#### ASPERGILLUS





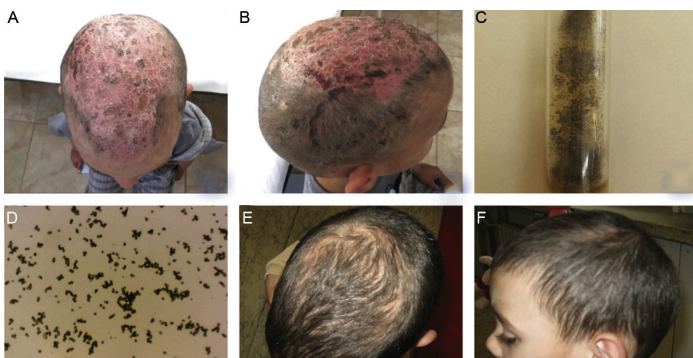
*Aspergillus* features a filamentous structure. The following elements comprise its cell structure:

- **Foot cell:** The vegetative hyphae are a component of the foot cell. The hypha obtains the nourishment for its growth through the foot cell's attachment to the substrate. Usually, the foot cell has an L or T shape. It produces the conidiophore as it develops.
- **Conidiophore:** It is slender, long, and perpendicular to the vegetative hyphae or foot cell. Conidiophore refers to the straight hyphal branch that enlarges at the apex giving rise to the vesicle.
- **Vesicle:** It has a spherical, elliptical, or club-shaped structure and forms a layer of phialide cells.
- **Conidia:** They are an exogenous reproductive component developed from sterigmata. The conidia are arranged in chains, with the youngest conidia at the base and the oldest at the top.
- **Mycelium:** It has a tubular, septate, multinucleated, multicellular, hyaline, and branched structure. It is surrounded by two layers, an outer layer made of chitin and an inner layer made of chitin.
- **Cytoplasm:** It has a granular appearance and is composed of cytoplasmic bodies like the endoplasmic reticulum, mitochondria, vacuoles, ribosomes, etc.

## DISEASES/BENEFIT INCLUDE TREATMENT

### HUMAN AND ANIMAL DISEASE

- It is less likely to cause disease in humans and animals unlike the other common species of *Aspergillus*.
- In rare cases, however, it can cause opportunistic invasive pulmonary aspergillosis in individuals with immune-compromised systems on inhalation of a damaged epithelial lining and respiratory tract system, causing severe lung disease.
- It can also cause **aspergillosis** in horticultural workers who are frequently exposed to inhalation of peat dust which is rich in *Aspergillus* spores.
- It is also a common cause of **otomycosis**, a type of fungal ear infection associated with temporary impaired hearing, pain, and severe cases that can damage the ear canal and the tympanic membrane.





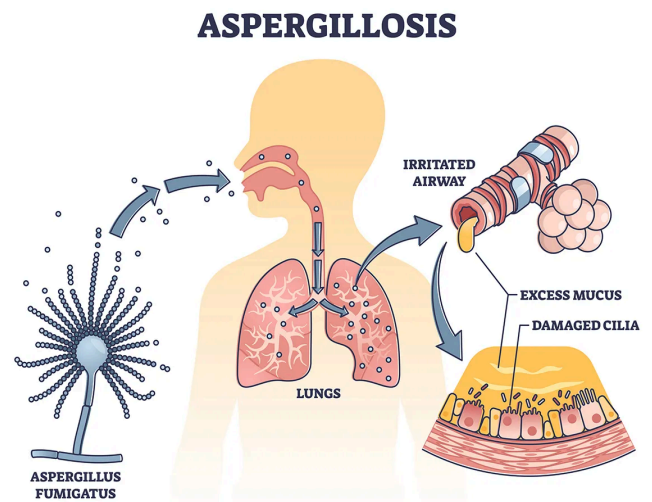
## TREATMENT OF ASPERGILLUS NIGER INFECTIONS

- Use of antifungal drugs for the treatment of opportunistic invasive aspergillosis such as itraconazole, Amphotericin B.
- For otomycosis use of itraconazole and anti-inflammatory none steroids to relieve the pain, such as acetaminophen.

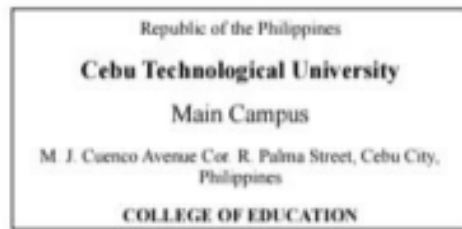
## Overview of Aspergillosis

**Aspergillosis** is an infection caused by *Aspergillus* fungi, which are commonly found in soil, plants, compost, and dust. People breathe in its spores daily without getting sick. However, individuals with weak immune systems or lung diseases can develop allergic reactions, lung infections, or severe invasive disease that can spread to organs like the brain and kidneys.

**Aspergillus** is not the same as “black mold” (*Stachybotrys chartarum*), although both are types of mold.



Who Is at Risk?



- **Allergic forms** – Common in people with asthma, bronchiectasis, or cystic fibrosis.
- **Chronic pulmonary forms** – Affect people with long-term lung diseases like COPD or tuberculosis.
- **Invasive aspergillosis** – Affects those with weakened immune systems (e.g., transplant patients, cancer patients, people on corticosteroids, diabetics, or those with low white blood cells).

### Types of Aspergillosis

1. **Allergic bronchopulmonary aspergillosis (ABPA)**
2. **Aspergilloma (fungus ball)**
3. **Chronic pulmonary aspergillosis**
4. **Invasive aspergillosis**

### Common Symptoms

#### Most symptoms affect the lungs and may include:

- Cough (sometimes with blood)
- Shortness of breath
- Wheezing
- Chest pain
- Fever
- Fatigue and weight loss

If the infection spreads, symptoms depend on the affected organ (e.g., eye pain, sinus congestion, skin ulcers, confusion, seizures, abdominal pain).

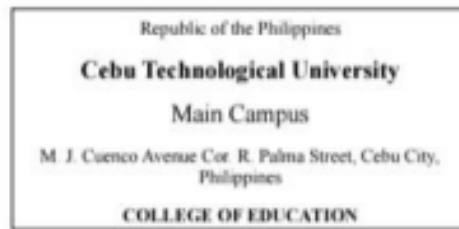
### Causes and Transmission

**Aspergillosis** occurs after inhaling fungal spores from the environment or through skin wounds. It is not contagious and cannot spread from person to person.

### Diagnosis

#### Doctors may use:

- Imaging tests (X-ray, CT scan)
- Blood tests
- Allergy tests



- Biopsy
- Fungal culture

### Treatment

#### Treatment depends on the type:

- Antifungal medications (e.g., voriconazole, amphotericin B)
- Corticosteroids for allergic forms
- Surgery (especially for fungus balls)

Some types can be cured, but invasive aspergillosis can be life-threatening and requires immediate treatment.

### Complications

#### Possible complications include:

- Lung scarring
- Bronchiectasis
- Organ damage
- Respiratory failure
- Sepsis

### Prevention

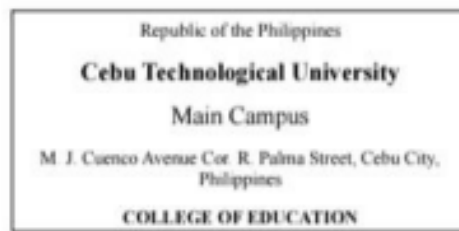
#### High-risk individuals should:

- Avoid dusty or moldy areas
- Wear N95 masks if exposed to dust
- Take preventive antifungal medicine if prescribed

## TAXONOMY OF ASPERGILLUS NIGER

### TAXONOMIC CLASSIFICATION OF ASPERGILLUS NIGER

TAXONOMIC RANK	CLASSIFICATION
Domain	Eukarya
Kingdom	Fungi



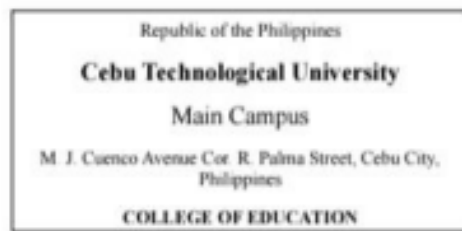
<b>Phylum</b>	<b>Ascomycota</b>
<b>Class</b>	<b>Eurotiomycetes</b>
<b>Order</b>	<b>Eurotiales</b>
<b>Family</b>	<b>Trichocomaceae</b>
<b>Genus</b>	<b>Aspergillus</b>
<b>Species</b>	<b>Aspergillus Niger</b>

**Aspergillus niger** is a microscopic fungus that belongs to the **Kingdom Fungi** and is commonly found in **soil, decaying plants, stored food products, and even indoor environments**. It is classified under **Domain Eukarya** because it has cells with a true nucleus and membrane-bound organelles. Like other fungi, it is heterotrophic in nature, which means it cannot produce its own food and instead absorbs nutrients from its surroundings.

In biological classification, *Aspergillus niger* belongs to the **Phylum Ascomycota**, also known as **sac fungi**. Organisms under this phylum reproduce by producing spores inside sac-like structures called asci. These spores are easily spread through air, allowing the fungus to grow in various environments. It is further classified under the Class Eurotiomycetes, which includes many mold species that play important roles in industry and biotechnology.

*Aspergillus niger* is grouped under the **Order Eurotiales and the Family Trichocomaceae**. These fungi are filamentous in nature, meaning they grow in the form of long thread-like structures called **hyphae**. A collection of these hyphae forms a mycelium, which functions in absorbing nutrients from the material on which the fungus grows.

Under the genus *Aspergillus*, *Aspergillus niger* is known for its **black spores**, which give the colony its dark appearance. This characteristic makes it easily recognizable in laboratory cultures. Scientifically, it is widely used in the production of **citric acid, enzymes, and other substances that are useful in food processing, pharmaceuticals, and various industrial applications**.



## TECHNOLOGY AND LATEST DEVELOPMENT

***Aspergillus niger*** is a filamentous fungus and a "generally recognized as safe" (GRAS) organism, functioning as a premier industrial cell factory for producing over 90% of the world's citric acid, as well as various industrial enzymes (glucoamylases, lipases, xylanases) and secondary metabolites.

Recent developments have shifted toward **using advanced gene-editing tools (CRISPR-Cas9), multi-omics analysis, and synthetic biology** to transform *A. niger* into a more robust "cell factory" with enhanced metabolic efficiency, faster growth, and broader product portfolios.

### Key Technological Advancements

**CRISPR-Cas9 & Genome Editing:** The application of CRISPR/Cas9 systems, particularly for marker-free deletion and multiple gene integration, has revolutionized *A. niger* strain engineering.

**Landing Pad System:** Researchers have developed a "landing pad" system for one-step, multi-copy integration of large DNA fragments (up to 30 kb) into the genome, facilitating the expression of large, complex metabolic pathways.

**Morphological Engineering:** Techniques like CRISPR disruption of cell wall-related genes (e.g., *agsA/agsB* and *sph3/uge3*) have been used to fully disperse *A. niger* mycelia, increasing biomass by 77.5% and protein content by 39.98%.

**Metabolic Engineering & NADPH Engineering:** To increase the production of target products (e.g., glucoamylase), engineers are focusing on strengthening metabolic flux through the pentose phosphate pathway (PPP) and reducing TCA pathways to increase NADPH supply.

**Cocultivation Strategies:** *A. niger* is increasingly used in coculture systems (e.g., with *Monascus ruber* or *Streptomyces*) to activate silent gene clusters and increase the production of novel bioactive metabolites.

### Latest Developments in Industrial Application

**High-Value Metabolites (Monacolin J):** *A. niger* has been engineered to produce Monacolin J (a precursor for simvastatin) with titers reaching 1851.52 mg/L, as an alternative to traditional production methods.



**Itaconic Acid Production:** Through the heterologous expression of *A. terreus* biosynthetic genes, *A. niger* is being engineered for the sustainable production of itaconic acid.

**Engineered Living Materials (ELMs):** *A. niger* mycelial pellets are being developed as self-supporting, regenerative materials for bio-sensors, packaging, and textiles, with tunable color and properties through the melanin synthesis pathway.

**Space Biotechnology:** *A. niger* is being studied for its ability to grow on the International Space Station, with potential applications in bio-mining or environmental control during long-term space flight.

**Enhanced Enzyme Production:** Metabolic engineering has improved the production of glucoamylase, reaching titers up to 30 g/L.

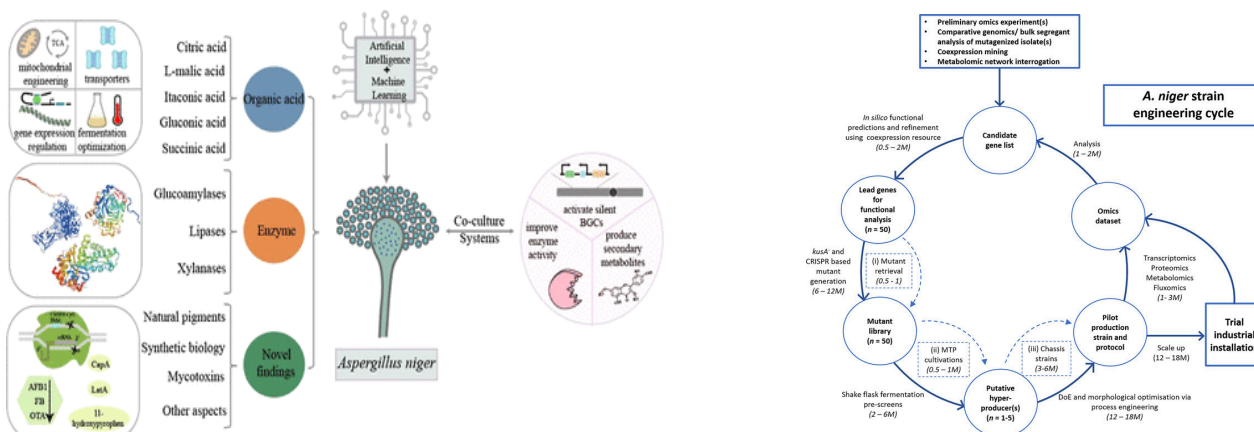
### Current Challenges and Future Directions

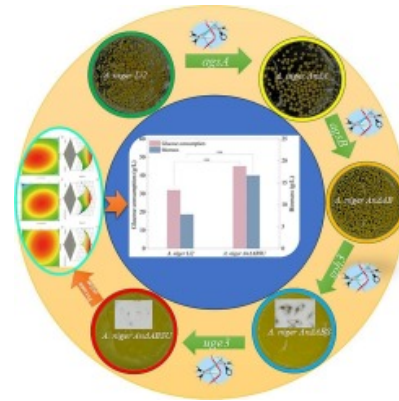
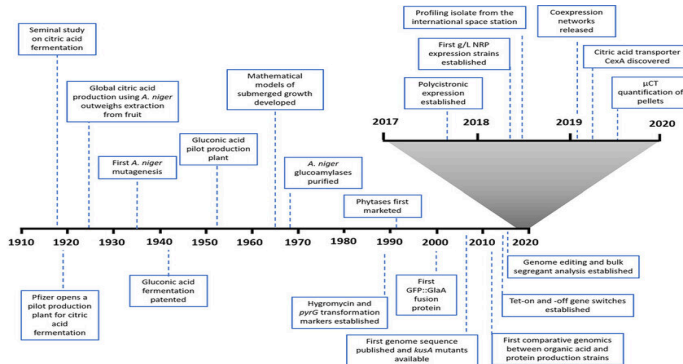
**Metabolic Stress:** High-level production of heterologous products often causes severe metabolic stress and growth retardation, necessitating further engineering of stress-tolerance pathways.

**Protein Secretion Limitations:** Despite high capacity, an incomplete understanding of the secretion mechanism still limits maximum yields.

**High-Throughput Screening:** Developing better high-throughput screening methods for *A. niger* mutants in submerged culture remains a priority.

**Green Biomanufacturing:** Future efforts are focusing on using low-cost waste biomass (e.g., agricultural waste) as feedstocks for *A. niger* fermentation to enhance sustainability.





## LABORATORY DIAGNOSIS OF ASPERGILLUS NIGER

- Microscopic examination to reveal the dark brown rough-edged conidia spores, brown conidiophore.
- Cultural examination using **Potato dextrose Agar**, **Czapek yeast Agar** and Malt Yeast Agar.
- Genomic sequencing of the fungi can be done for identification and differentiation from other fungi.
- **Thin-layer chromatography** can be used for the identification and quantification of ochratoxin mycotoxin.



# Candida Albicans (Yeast Infection)

## Introduction

Fungi are eukaryotic organisms found in the form of yeasts, molds, or dimorphic fungi (Arora, D. R., & Arora, B. B., (2024). *Textbook of Microbiology with parasitology* (7th ed). CBS Publishers & Distributors Pvt Ltd). *Candida albicans* is a pathogenic yeast-like fungus that grows partly as yeast and partly as elongated cells resembling hyphae which form pseudo mycelium. *Candida albicans* can be identified from other candida species by growth characteristics, sugar assimilation, and fermentation tests. It produces germ tubes within two hours when incubated in human serum at 37-degree celsius. It presents as white patches on the tongue, throat, and other mouth areas. Soreness and difficulty in swallowing include other symptoms associated with thrush. The vagina, when affected with *Candida*, is called a **yeast infection**.

## Taxonomy & Classification

**Scientific name:** Candida Albicans

**Common name:** Candida, Yeast (opportunistic yeast). Thrush fungus

**Kingdom:** Fungi

**Phylum:** Ascomycota

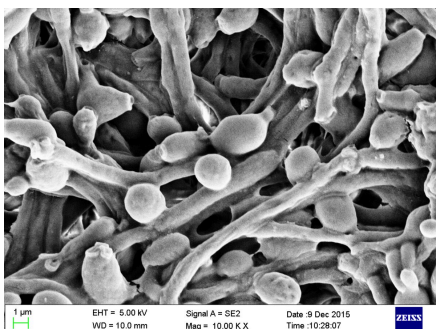
**Class:** Saccharomycetes

**Order:** Saccharomycetales

**Family:** Saccharomycetaceae

**Genus:** Candida

**Species:** Candida albicans





**Calbicans** is commonly used as a model organism for fungal pathogens. It is generally referred to as a dimorphic fungus since it grows both as yeast and filamentous cells.

### Morphology/Characteristics

- Small, oval, measuring 2-4  $\mu\text{m}$  in diameter.
- Yeast form, unicellular, reproduces by budding.
- Single budding of the cells may be seen.
- Both yeast and pseudo-hyphae are **gram-positive**.
- Encapsulated and diploid, also form true hyphae.
- Polymorphic fungus (yeast and pseudohyphal form)
- Can form biofilms
- Normal condition: Yeast
- Special condition (pH, Temperature): Pseudohyphae
- 80-90% of the cell wall is carbohydrate



**Yeast**



**Pseudohyphae**



**Hyphae**

### Cultural Characteristics of Candida Albicans





### **Candida albicans on SDA**

- Creamy, pasty colonies, smooth after 24-48 hours at 25-37°C
- Yeast smell (odour)

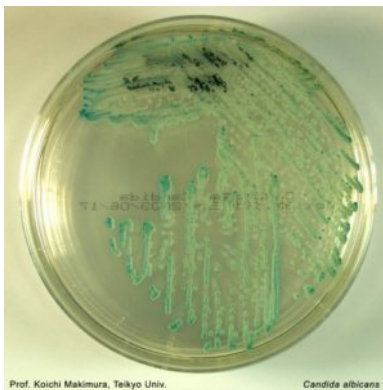


**Candida albicans on Blood Agar**

- White creamy colored
- Foot-like extensions from the margin.

### **Candida albicans on PDA**

- Smooth creamy colonies after 24-48 hours



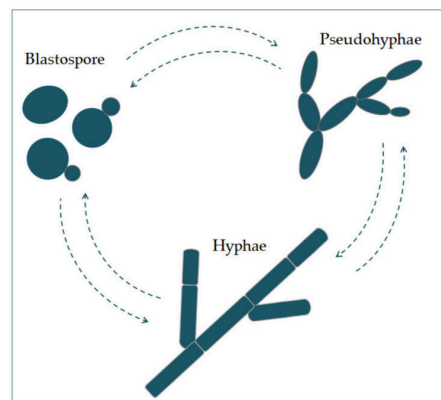
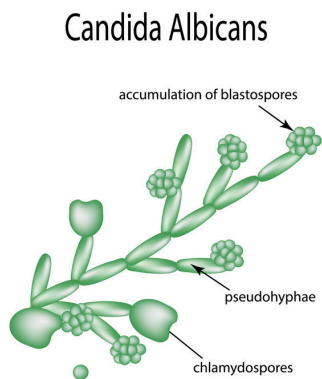
**Candida albicans on Chromagar**

- Green colonies



## Anatomy, Parts and Functions

- **Yeast (Blastospore):** Small, round cells that reproduce by budding; primarily involved in colonization and dissemination through the bloodstream.
- **Hyphae:** Long, branching, tubular cells that are highly invasive; they penetrate epithelial and endothelial cells using mechanical pressure and enzymatic activity. Hyphae are essential for tissue invasion.
- **Pseudohyphae:** Elongated yeast cells that remain attached after division,



representing a transitional form between yeast and true hyphae.

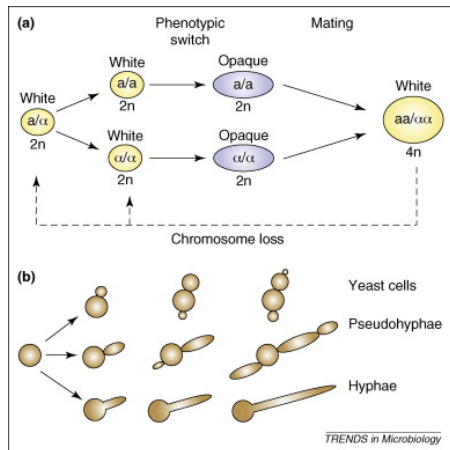
- **Chlamydozoospores:** Thick-walled, large, asexual spores produced under adverse environmental conditions; thought to aid in survival.

## Life Cycle of Candida Albicans

- Asexual and doesn't perform meiosis
- Ability to grow with three distinct morphologies- yeast, pseudo-hyphae and true hyphae
- Para-sexual life cycle
- Switch between different phenotypes
- Efficient mating requires the diploid cells of opposite mating types first to switch from the more common "white" phase to the "opaque" phase and then undergo cell fusion.



- The resulting tetraploid strains can return to the diploid state via a non-meiotic parasexual program of concerted chromosome loss.
- **White form:** white and rounded cells forming dome-shaped colonies
- **Opaque form:** opaque, elongated cells forming a flatter colony.
- Opaque form is more efficient for mating than the white form



## Diseases/Benefit include Treatment

### 1. Urinary yeast infection

#### Infection

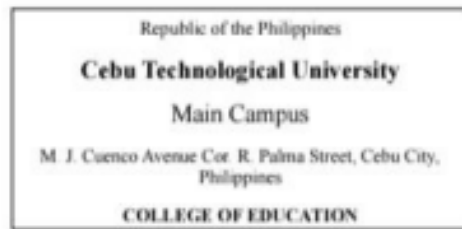
A fungal urinary tract infection caused by *Candida* species. It may affect the bladder and sometimes the kidneys. Risk factors include antibiotic use, diabetes, urinary catheters, and weak immunity.

#### Symptoms

- Frequent urination
- Burning or pain when urinating
- Abdominal or pelvic pain
- Blood in urine
- Some people may have no symptoms

#### Treatment

- Fluconazole (for symptomatic cases)
- Removal of catheter if present



## 2. Genital Yeast Infection

### Infection

Commonly caused by *Candida albicans*. It happens when normal bacteria (Lactobacillus) decrease, allowing Candida to overgrow. Risk factors include antibiotics, diabetes, pregnancy, hormone therapy, and weak immunity.

### Symptoms

- Itching and burning
- Redness and swelling
- Pain during urination or sex
- Thick white or watery discharge
- Rash (in females or males)

### Treatment

- Antifungal creams, suppositories, or pills
- Oral fluconazole (single or longer dose for severe cases)

## 3. Oral Thrush

### Infection

Overgrowth of *Candida albicans* in the mouth. It may spread to the throat or esophagus. Common in people taking antibiotics, diabetics, denture wearers, and immunocompromised individuals.

### Symptoms

- White patches in the mouth
- Mouth pain or burning
- Difficulty swallowing
- Loss of taste
- Cotton-like feeling in the mouth

### Treatment

- Antifungal medications (nystatin, clotrimazole)
- Oral fluconazole for severe cases

## 4. Mucocutaneous (Skin) Candidiasis

### Infection



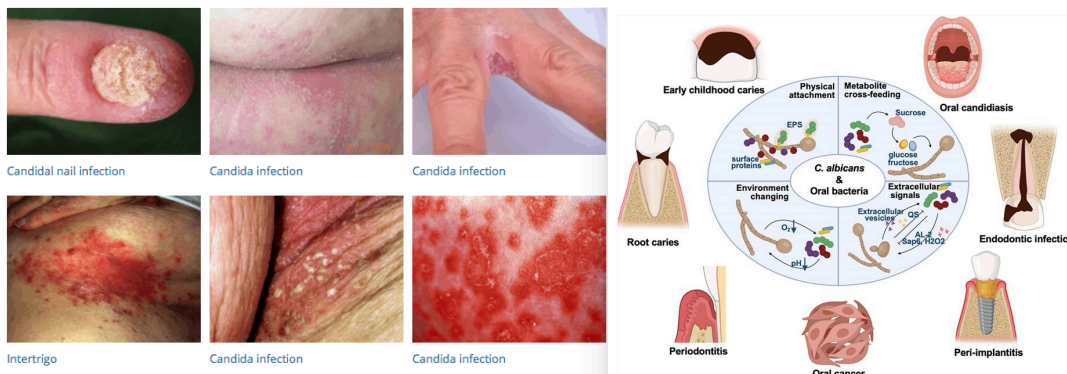
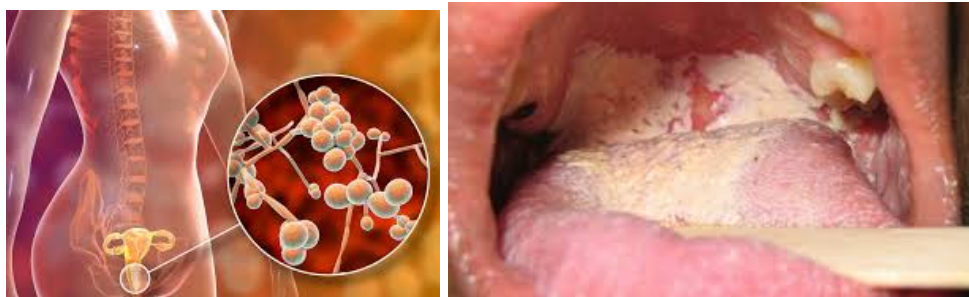
Fungal infection of the skin and mucus membranes, especially in warm and moist areas (armpits, groin, under breasts, between fingers/toes).

## Symptoms

- Red rash
- Itching
- Blisters
- Thickened skin or white curd-like substance

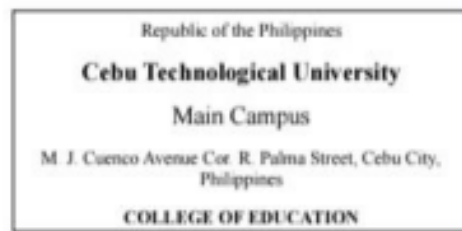
## Treatment

- Antifungal creams (clotrimazole, miconazole, econazole)
- Keep area clean and dry
- Oral fluconazole for widespread infections



## TECHNOLOGY AND LATEST DEVELOPMENT

*Candida albicans* is a dimorphic opportunistic yeast and a major human fungal pathogen, primarily studied for its virulence, drug resistance, immune interactions, and antifungal strategies (Moyes et al., 2016,). Recent technological developments aim to improve its diagnosis, treatment, and genetic understanding (Vyas et al., 2015)



## **Latest Technological Developments in *C. albicans* Management**

*Candida albicans* is an opportunistic human fungal pathogen that is a leading cause of severe, often fatal, invasive infections. Due to the rise of antifungal resistance, particularly against commonly used azoles and echinocandins—research has shifted toward innovative, multi-faceted, and nanotechnology-based approaches to combat this pathogen

### **Nanozyme-Based Catalytic Therapy (NBCT):**

Materials with enzyme-like activity, such as peroxidase-mimicking iron oxide nanoparticles and MnOx/GDY nanoclusters, generate reactive oxygen species (ROS) to kill *C. albicans* and penetrate drug-resistant biofilms.

### **Active Nanorobots & Magnetotherapy:**

Magnetically controlled nanorobots, like parachute-like Janus nanorobots (PJNs), physically disrupt biofilms and move autonomously in response to magnetic fields.

### **Nanocarrier Drug Delivery Systems:**

Nanoliposomes and metal nanoparticles (silver, gold, zinc oxide) deliver antifungal agents directly to infection sites, enhancing penetration through dense biofilms and reducing toxicity.

### **CRISPR-Based Genome Editing:**

CRISPR-Cas9 enables rapid, precise editing of both alleles in the diploid genome of *C. albicans*, helping study virulence factors and identify new drug targets.

### **Rapid Molecular Diagnostics:**

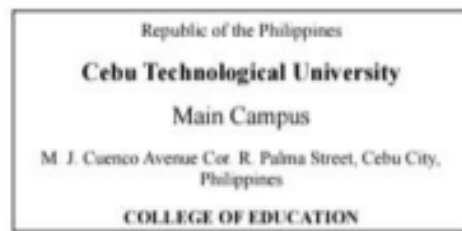
Tools like the T2Candida panel and magnetic nanobead biosensors allow fast, species-level identification directly from blood, providing results in 3–5 hours or under 5 minutes for immediate treatment.

### **Bio-Inspired & Smart Delivery Vehicles:**

Cell membrane-coated nanoparticles, such as red blood cell membranes, camouflage drug carriers for targeted binding to *C. albicans*, improving therapeutic efficiency.

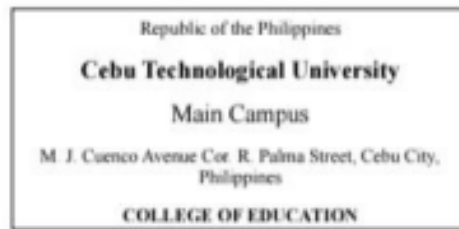
### **Recent *C. albicans* Research:**

- **Biofilm-Induced Resistance:** *C. albicans* biofilms can show 30 to 2,000 times higher resistance to drugs like Amphotericin B and fluconazole compared to planktonic cells, necessitating the use of novel anti-biofilm treatments.



- Virulence Factors: The yeast-to-hypha transition is key to pathogenicity, often driven by host signals and environmental factors. The toxin candidalysin, encoded by the *ECE1* gene, has been identified as a critical factor in epithelial damage.
- Drug Synergies: Combination therapies, such as linking traditional antifungal agents with novel compounds (e.g., PAN, an inhibitor of Hsp90) or using "anti-virulence" compounds that inhibit biofilm formation without killing the fungus (thereby reducing resistance development), are promising.
- Microbiota Interaction: The presence of *C. albicans* in mixed biofilms with bacteria (e.g., *Staphylococcus aureus*) enhances the bacterial resistance to antibiotics, with fungal beta-glucans protecting the bacteria.

The future of *C. albicans* management lies in integrating these advanced technologies, such as AI-driven diagnostics and multi-modal,, target-specific nano-agents, to improve patient outcomes in the face of rising drug resistance



## Puccinia graminis (Stem Rust)



**Introduction:** Cereal crops such as wheat, barley, rye, and oats are the backbone of global food security, feeding billions of people worldwide. However, these crops are constantly threatened by fungal pathogens, with *Puccinia graminis* the causal agent of stem rust standing out as one of the most destructive. Stem rust has historically caused devastating epidemics, leading to widespread crop failures and economic losses across

continents.

The fungus is remarkable for its complex life cycle, involving multiple spore stages and an alternate host (commonly barberry), which makes its management challenging. Its ability to evolve new virulent races has repeatedly overcome resistant cultivars, forcing scientists and farmers to continually adapt.

*Puccinia graminis* is a species of fungus that causes **stem rust**, one of the most destructive diseases of cereal crops such as wheat, barley, rye, and triticale. It belongs to the kingdom **Fungi**, division **Basidiomycota**, class **Pucciniomycetes**, order **Pucciniales**, family **Pucciniaceae**, and genus **Puccinia**

### Morphology

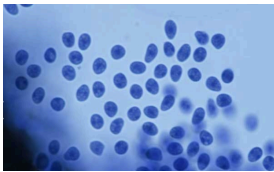
- Obligate biotrophic fungus (requires living host).
- Produces five spore stages: pycniospores, aeciospores, urediniospores, teliospores, basidiospores.



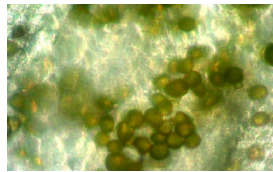
- Urediniospores: brick-red, powdery, infectious stage.
- Teliospores: black, thick-walled, survival stage.
- Spores adapted for wind dispersal, enabling rapid spread.

### Five Spore Stages:

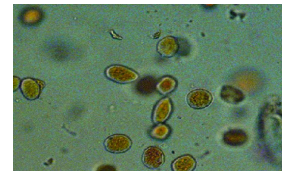
#### Pycniospores



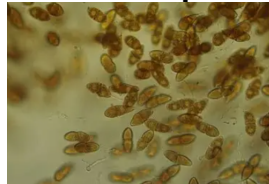
#### Aeciospores



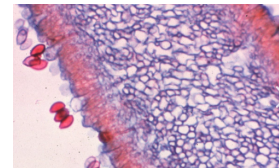
#### Urediniospores



#### Teliospores



#### Basidiospores



#### Pycniospores

- Found on barberry leaves.
- Act like “male cells” for reproduction.

#### Aeciospores

- Also on barberry.
- Spread to cereal crops (like wheat).

#### Urediniospores

- Red spores on wheat stems/leaves.
- Multiply quickly and spread disease during the season.

#### Teliospores

- Black, thick spores on wheat at the end of the season.
- Resting stage that survives harsh conditions.

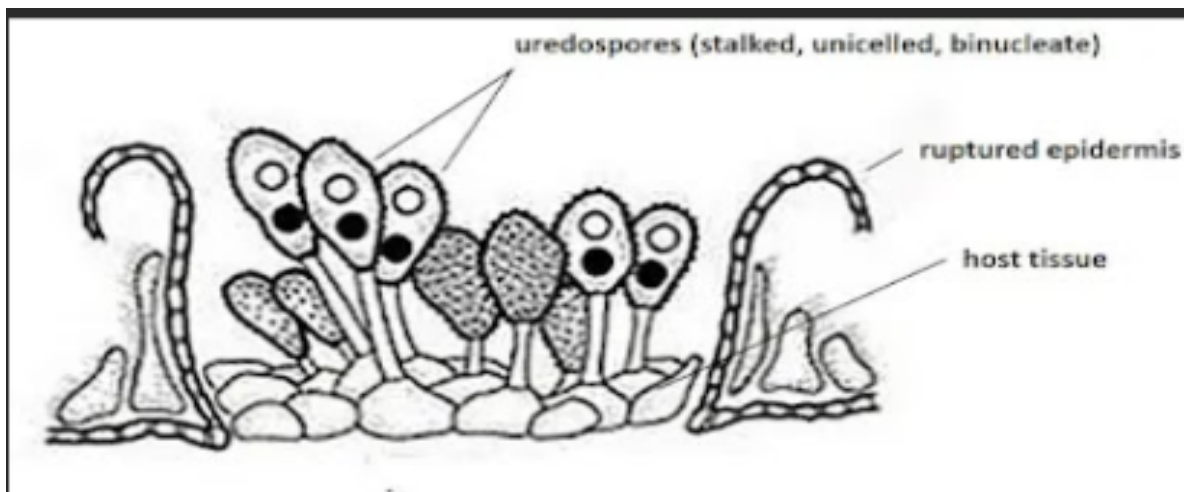
#### Basidiospores

- Grow from teliospores.



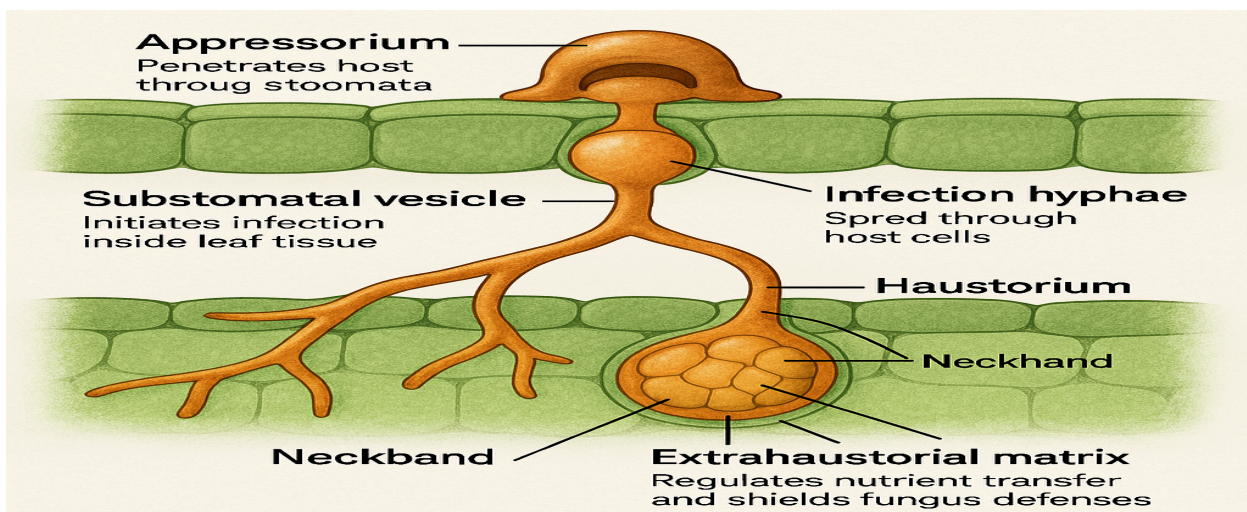
- Travel back to barberry to restart the cycle.

## Puccinia graminis microscopic visual



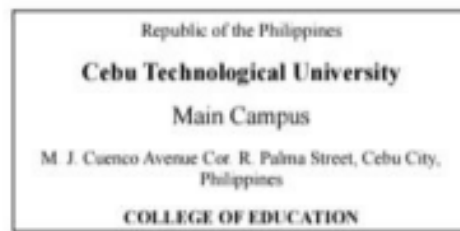
### Anatomy & Structure – Parts and Functions

- Appressorium – penetrates the host through stomata.
- Substomatal vesicle – initiates infection inside leaf tissue.
- Infection hyphae – spread through host cells.
- Haustorium – specialized feeding organ extracting nutrients.
- Neckband/extrahaustorial matrix – regulates nutrient transfer and shields fungus from host defenses.





<b>Taxonomic rank</b>	<b>Name</b>	<b>Description</b>
<b>Kingdom</b>	Fungi	Eukaryotic organisms that absorb nutrients from other organisms; includes molds and rusts.
<b>Phylum</b>	Basidiomycota	Fungi that produce spores on club-shaped structures called basidia.
<b>Class</b>	Urediniomycetes	Rust fungi; obligate parasites with complex life cycles involving multiple spore stages.
<b>Order</b>	Uredinales	Includes rust fungi that infect plants, often requiring two hosts to complete their life cycle.
<b>Family</b>	Pucciniaceae	A large family of rust fungi, many of which infect cereal crops and grasses.
<b>Genus</b>	Puccinia	The largest genus of rust fungi, known for causing plant diseases like stem rust.
<b>Species</b>	Puccinia graminis	Causes stem rust in wheat, barley, rye, and oats; known for its devastating impact on agriculture.



## Diseases Caused by *Puccinia graminis*

- **Wheat Stem Rust (Black Rust):** Caused by *Puccinia graminis* f. sp. *tritici* (Pgt), this is one of the most economically damaging diseases of wheat worldwide.
- **Symptoms:** Infected plants display reddish-brown, elongated pustules (uredinia) on stems, leaf sheaths, and sometimes heads, which break through the epidermis.
- **Impact:** Severe infections can cause up to 70% yield loss and reduce grain quality by shriveling kernels.
- **Epidemiology:** It is a heteroecious fungus that requires two hosts to complete its life cycle: a cereal crop and the common barberry (*Berberis vulgaris*).

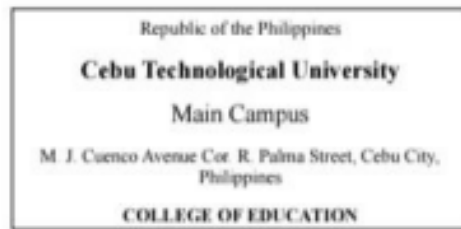
## Treatment and Management of *Puccinia graminis*

-Control strategies focus on minimizing yield loss through integrated pest management:

- **Chemical Control (Fungicides):** Application of systemic fungicides is effective, particularly those containing triazoles (e.g., propiconazole) or strobilurins.
  - Effective Agents: Nativo SC 300 (trifloxystrobin + tebuconazole) and Tilt® 250EC (propiconazole) have been shown to significantly reduce terminal rust severity and increase thousand-kernel weight.
  - Application Timing: Spraying should ideally occur before or immediately after the first symptoms are observed.
- **Host Resistance:** Planting resistant wheat cultivars is the most sustainable management strategy. However, the emergence of new races like Ug99, which overcomes previously effective resistance genes (e.g., Sr31), poses a major threat.
- **Cultural Practices:** Eradication of the alternative host (common barberry) reduces initial inoculum. Managing nitrogen fertilizer rates is also important, as higher rates can increase disease pressure.

## Potential "Benefits" (Uses in Research)

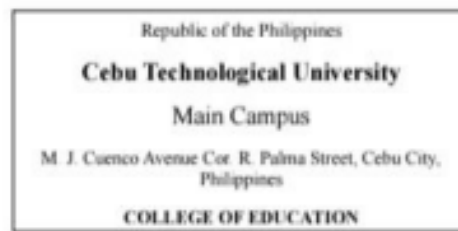
- **Allergenic Extract:** *Puccinia graminis* extract is used in non-standardized allergenic testing, as it can trigger immune responses.



- **Biological Research:** It is used as a model organism in molecular studies, such as identifying candidate susceptibility genes in plants.
- **Virulence Studies:** The fungus is used to study how specialized pathogens overcome plant defenses, aiding in the development of resistant crops

## Technology & Latest Discoveries

- **DNA Tools** – Scientists use genome sequencing to study the fungus's genes and understand how it infects plants.
- **Resistance Genes** – New wheat and barley varieties are bred with special genes (*Sr* and *Rpg1*) that help fight stem rust.
- **Portable Testing** – Quick genotyping devices can detect rust strains in the field, helping farmers act faster.
- **Population Studies** – Research shows stem rust spores can travel long distances, explaining why new strains appear in different countries.
- **Future Work** – Scientists aim to combine multiple resistance genes (“gene stacking”) to make crops stronger and more durable.



# USTILAGO MAYDIS

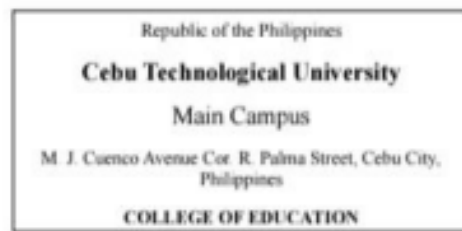
## INTRODUCTION



**Ustilago maydis** is a dimorphic plant-pathogenic fungus that infects maize and causes a disease known as **corn smut**.

A **plant-pathogenic fungus** is a microorganism that invades plant tissues

and disrupts normal plant physiology, leading to structural deformities and reduced crop productivity. This organism belongs to a group of fungi called **biotrophs**, meaning it depends on living host cells to survive and complete its life cycle. Unlike necrotrophic fungi that kill plant tissue immediately, *U. maydis* maintains host cell viability during early infection stages while extracting nutrients for growth and reproduction. The fungus primarily infects **Zea mays (corn)**, where it induces abnormal swelling of plant tissues known as **galls**. These galls later rupture and release large numbers of dark spores that enable the fungus to spread and survive in the environment. Despite being a destructive agricultural pathogen, *Ustilago maydis* is also widely studied as a model organism in



molecular biology and genetics because of its simple genome, well-understood life cycle, and ease of laboratory cultivation.

## TAXONOMY

### KINGDOM: FUNGI

- includes eukaryotic organisms that absorb nutrients through external digestion and possess cell walls made of chitin.

### PHYLUM: BASIDIOMYCOTA

- a group characterized by producing sexual spores on specialized structures called **basidia**. However, unlike mushrooms that form large fruiting bodies, *U. maydis* is part of a specialized lineage of plant parasite

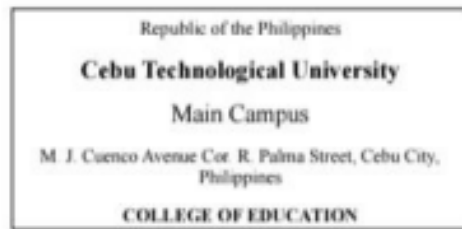
### SUBPHYLUM USTILAGINOMYCOTINA

- which includes smut fungi that infect grasses and cereals. These fungi are obligate parasites, meaning they require a living host to reproduce naturally.

### CLASS :USTILAGINOMYCETES

### ORDER: USTILAGINALES

- All members are plant-infecting fungi that produce black, powdery spores resembling soot, giving rise to the term “smut.”



## GENUS: USTILAGO

- Comprises multiple species are host-specific to maize

## ALTERNATIVE NAME: *Mycosarcoma maydis*

- Proposed based on the modern phylogenetic molecular evidence, the original name *Ustilago Maydis* remains the most widely used in scientific literature.

## MORPHOLOGY

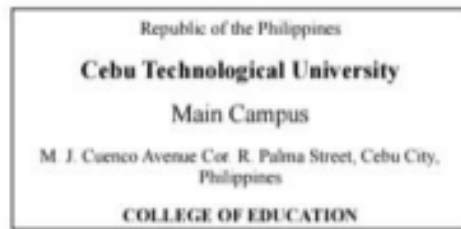
The morphology of *Ustilago maydis* is characterized by **dimorphism**, which refers to the ability of an organism to exist in two distinct structural forms depending on environmental conditions and reproductive stage:

### 1. YEAST-LIKE FORM

- The fungus exists as unicellular, oval-shaped haploid cells that reproduce through budding, similar to common yeast
- This stage is typically non-pathogenic and allows the fungus to survive outside the host in soil or laboratory environments

### 2. DIKARYOTIC FILAMENTOUS PHASE

- The infectious stage is responsible for invading plant tissues.



- Two compatible mating types encounter each other; they fuse and transition into the filamentous form, which consists of elongated hyphae that form a multicellular network.

### 3. TELIOSPORES

- thick-walled, dark-colored survival spores produced within plant galls.
- These spores are highly resistant to environmental stresses such as heat, drought, and ultraviolet radiation, allowing the fungus to persist in soil for years and initiate future infections.

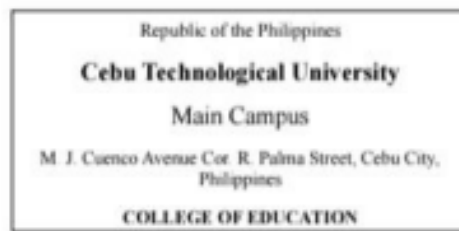
## ANATOMY

Though fungi lack complex organs, *u. Maydisl* has specialized microscopic structures for survival and infections:

### SPORIDIA

- a haploid, yeast-like cell formed after spore germination. These cells play a crucial role in vegetative growth and mating, allowing genetic recombination that leads to the infectious stage

### HYPHAE



- a tubular filament composed of chitin-rich cell walls that provide rigidity and protection. Hyphae grow intercellularly within plant tissues, meaning they expand between plant cells rather than destroying them immediately, helping the fungus evade early immune detection.

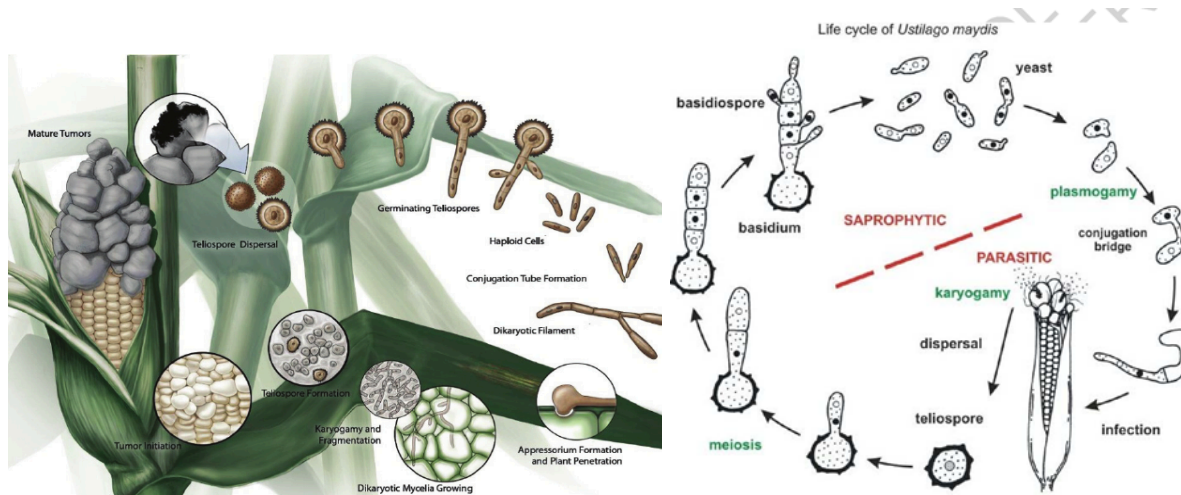
### **APPRESSORIUM**

- A highly specialized infection structure formed during host invasion. This structure adheres tightly to the plant surface and generates mechanical pressure while releasing enzymes that degrade plant cell walls, enabling penetration into host tissues.

### **EFFECTOR PROTEINS**

- Secreted by the fungus, it manipulates host cellular processes by suppressing plant immunity, altering metabolism, and redirecting nutrients toward fungal growth.

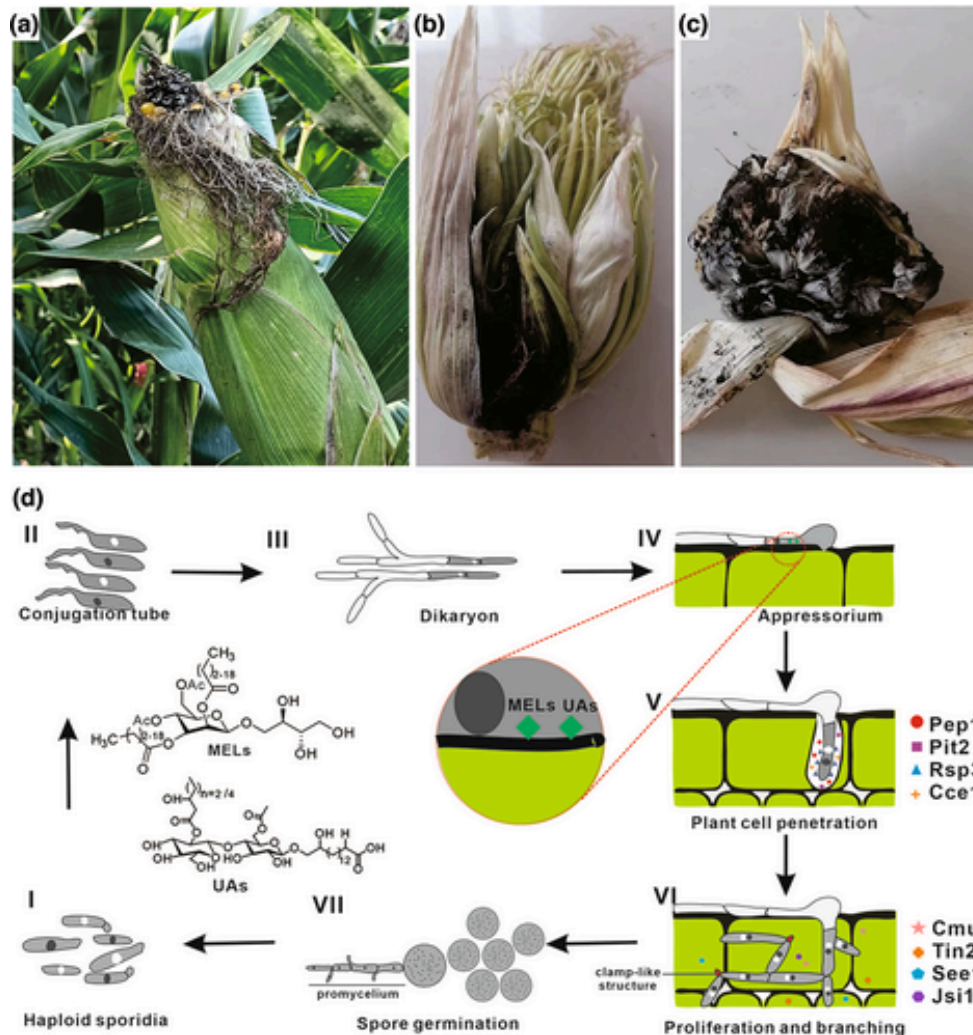
## **LIFE CYCLE**



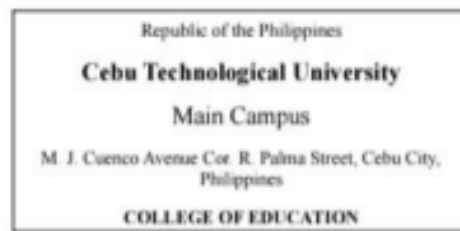
The life cycle of *Ustilago maydis* is complex and cyclical, enabling it to persist in agricultural environments across growing seasons. It begins with **teliospores that remain dormant in soil** or plant debris during unfavorable conditions. When environmental factors such as moisture and temperature become suitable, these spores germinate and produce a structure called a **basidium**, where meiosis occurs. This process generates **haploid sporidia**, which are yeast-like cells capable of independent survival. Infection begins when two **compatible mating types fuse**, forming **dikaryotic hyphae** that represent the pathogenic phase. These hyphae penetrate maize tissues using appressoria and begin colonizing the host internally. As the fungus grows, it secretes effector proteins that manipulate plant cellular pathways, leading to uncontrolled cell division and **tumor formation**. Within these tumors, new **teliospores**



develop and mature. Eventually, the **galls rupture**, releasing spores back into the environment, thereby completing the cycle and enabling future infections.



Corn smut and infection of *Ustilago maydis*. (a) Ripe corn cobs mildly infected with corn smut, (b) severely infected ears of corn smut, (c) tissue filled with mature corn smut spores, and (d) the life cycle of *U. maydis*. Effectors: Pep1



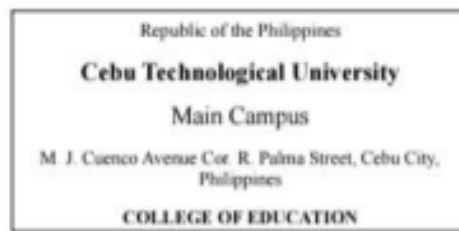
(protein essential during penetration 1), Pit2 (protein important for tumours 2), Rsp3 (repetitive and secreted protein 3), Cce1 (cysteine-rich core effector 1), Cmu1 (chorismate mutase 1), Tin2 (tumour-inducing effector 2), See1 (seedling efficient effector 1), and Jsi1 (jasmonate/ethylene signalling inducer 1). MEL, mannosyl erythritol lipid; UA, ustilagic acid.

## DISEASE CAUSED — CORN SMUT



Common smut of corn, caused by *Ustilago maydis*, is easily identified by tumor-like galls that form on actively growing host tissues and contain masses of dark, sooty teliospores. Throughout most

of the world, common smut is considered to be a troublesome disease of corn, but in central Mexico, galls on ears of corn are considered an edible delicacy known as cuitlacoche (Syn. huitlacoche). In addition to the practical significance of causing a prevalent disease and being an edible fungus, *U. maydis* also has been used as a model organism to study a variety of interesting biological phenomena. It is characterized by **tumor-like swellings that develop on various parts of the maize plant.** The



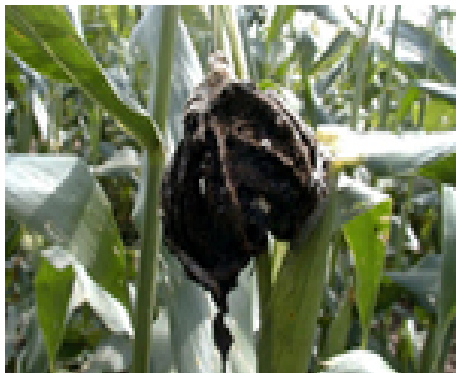
disease begins when fungal hyphae **invade young, actively growing tissues**, particularly in areas that are wounded or stressed.

## SYMPTOMS PROGRESSION

Early symptoms appear as small, **white, fleshy galls** that gradually enlarge as fungal growth continues. As the disease progresses, these galls darken and fill with black, powdery teliospores, which give the disease its characteristic smut-like appearance.

## AFFECTED PLANT PARTS

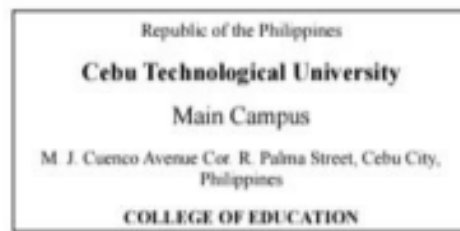
***Ustilago maydis* infects two hosts: maize (*Zea mays*) and teosinte (*Zea mexicana*).**



Like other smut diseases, common smut of corn derives its name from the sooty masses of teliospores found on infected host plants. The most obvious symptoms are tumor-like galls that vary in size from less than 1 cm to more than 30

cm (0.4-12 inch) in diameter. All meristematic tissues are susceptible to infection.





Galls are found most frequently on **ears, tassels, stalks, nodal shoots, and mid-ribs of leaves** . Even though galls may form on many above-ground parts of the plant, infection is local (i.e., the host is not colonized systemically).



Occasionally, galls develop beneath the soil surface when the apical meristem of a young plant is infected.

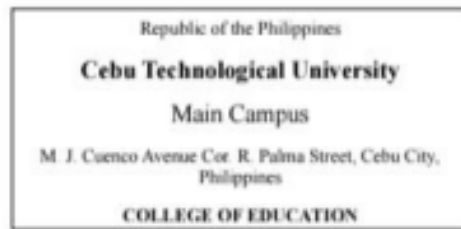
Environmental conditions such as warm temperatures, high humidity, and mechanical injury significantly increase

infection rates. Although the disease can reduce yield and contaminate harvested grain, its economic impact varies depending on management practices and regional agricultural conditions.

## TREATMENT

Management of *Ustilago maydis* primarily focuses on prevention because there is **no effective cure** once the fungus has established itself inside plant tissues.

**Cultural control methods** are widely used, including **early removal and destruction of infected galls** to prevent spore dispersal.



**Crop rotation-** is another effective strategy, as it reduces the buildup of spores in the soil by alternating maize with non-host crops.

The development and use of **resistant maize varieties** represent one of the most sustainable control measures, as plant breeders select for genetic traits that enhance natural immunity against fungal infection.

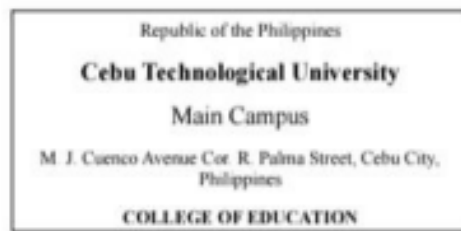
**Proper field management practices** such as minimizing plant injuries, maintaining balanced fertilization, and reducing environmental stress can also lower susceptibility.

**Chemical control methods-** have limited effectiveness because fungicides struggle to penetrate plant tissues once the fungus becomes systemic. However, ongoing research explores biological control agents and advanced disease management strategies.

## **BENEFITS OF USTILAGO MAYDIS**

Despite its role as a plant pathogen, *Ustilago maydis* has several beneficial applications in food and science. One of the most notable is its :

- **Culinary use as huitlacoche**, a traditional Mexican delicacy made from immature corn galls harvested before spore maturation. These fungal galls are valued for their unique earthy flavor and **high nutritional content**, including elevated protein levels, essential amino acids such as lysine, and antioxidant compounds.

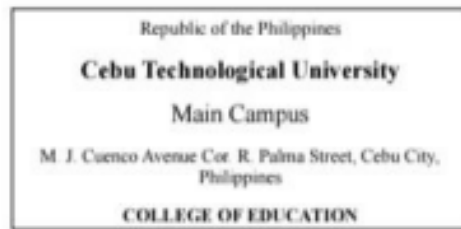


- **Scientific research, *U. maydis* serves as a model organism** because of its fully sequenced genome, ease of laboratory cultivation, and clearly defined infection stages. **Researchers** use it to study host-pathogen interactions, fungal genetics, cell cycle regulation, and signal transduction pathways.
- **Applications in biotechnology**, including the study of virulence genes, development of disease-resistant crops, and exploration of fungal enzymes for industrial use.

## MODERN TECHNOLOGIES AND DISCOVERIES

Advances in modern biotechnology have significantly expanded our understanding of *Ustilago maydi*:

- **Genome sequencing** has allowed scientists to identify genes responsible for pathogenicity, **mating compatibility**, and environmental adaptation.
- **The development of CRISPR gene-editing technology** enables targeted modification of fungal genes, allowing researchers to study virulence mechanisms and design weakened strains for research purposes.
- **Transcriptomic approaches such as RNA sequencing** provide insights into gene expression patterns during different stages of infection, revealing how the fungus communicates with its host and adapts to stress conditions.
- Recent **breakthroughs in effector biology** have identified hundreds of secreted proteins that manipulate host immunity and regulate tumor development.



- **Synthetic biology** approaches are also being explored, including engineering strains for controlled huitlacoche production and industrial enzyme applications.
- **Climate change research** is investigating how rising temperatures and changing environmental conditions may influence spore survival and disease distribution.

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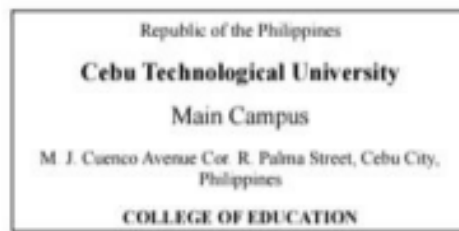
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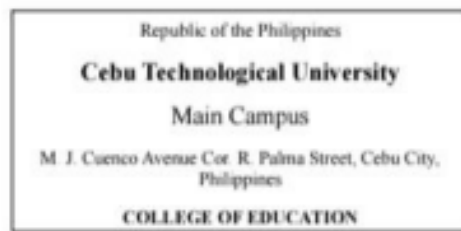
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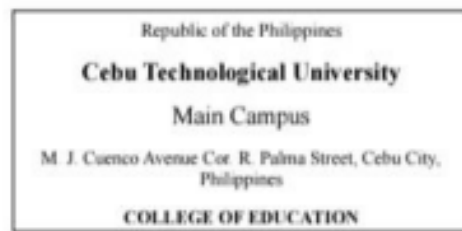
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