Fungal Physiology

Fourth-year students, general education

(Biological and Geological Sciences Division)

Dr. Moaz Mohamed Hamed

Assistant Professor of microbiology, Marine microbiology department, National Institute of Oceanography and Fishers, Egypt.

رؤية الكلية

تسعى الكلية الى مساعدة الجامعة فى تحقيق اهدافها الاستراتيجية من خلال ان تكون واحدة من الكليات المتميزة والمنافسة داخليا وخارجيا فى التعليم وخدمة المجتمع والبحث العلمى من خلال تحقيق مستوى رفيع من الاداء وتقديم خريج متميز يقابل الاحتياجات المتعددة بسوق العمل الداخلى والاقليمى والخارجى

رسالة الكلية

تهدف كلية التربية بالغردقة الى التميز من خلال:

- إعداد المربين والمعلمين المتخصصين والقادة إعداداً أكاديمياً ومهناً وثقافياً فى مختلف التخصصات التربوية.
- تنمية القدرات المهنية والعلمية للعاملين فى ميدان التربية والتعليم بتعريفهم بالاتجاهات التربوية الحديثة.
- إجراء البحوث والدراسات فى التخصصات التربوية والمختلفة بالكلية.
- نشر الفكر التربوى الحديث واسهاماتة لحل مشكلات البيئة والمجتمع.
- تبادل الخبرات والمعلومات مع الهيئات والمؤسسات التعليمية والثقافية المختلفة.
- تنمية جوانب شخصية الطلاب ورعاية الموهوبين والمبدعين.

Introduction

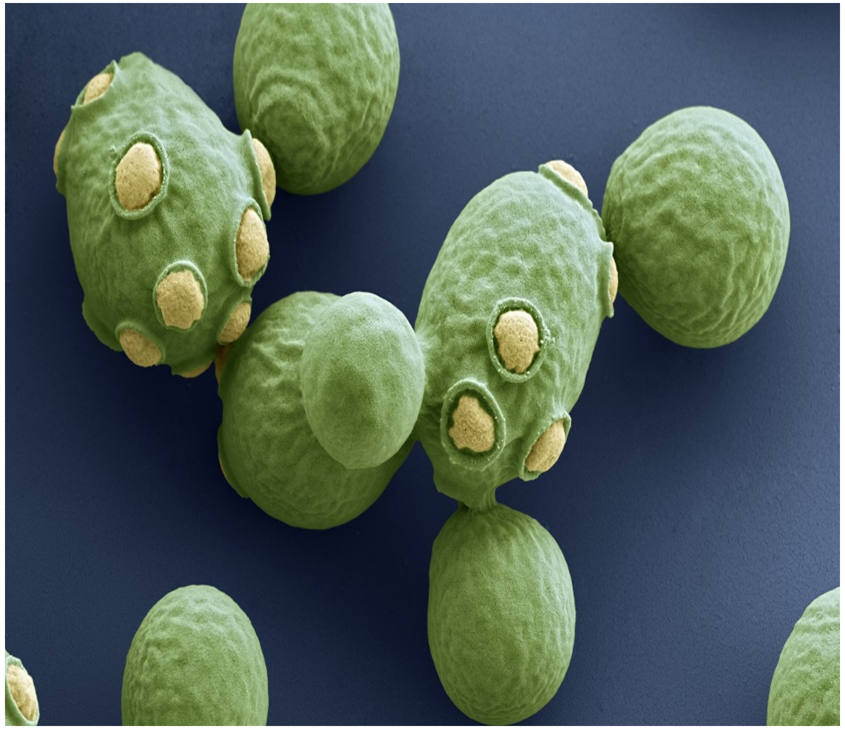
- Fungal physiology refers to the nutrition, metabolism, growth, reproduction, and death of fungal cells. It also generally relates to the interaction of fungi with their biotic and abiotic surroundings, including cellular responses to environmental stress.
- The physiology of fungal cells impacts significantly the environment, industrial processes, and human health. In relation to ecological aspects, the biogeochemical cycling of carbon in nature would not be possible without the participation of fungi acting as primary decomposers of organic material.
- Furthermore, in agricultural operations, fungi play important roles as mutualistic symbionts, pathogens, and saprophytes, where they mobilize nutrients and affect the physicochemical environment, or can be exploited as agents of biocontrol or as biofertilizers. Fungal metabolism is also responsible for the detoxification of organic pollutants and for bioremediating heavy metals and other recalcitrant chemicals in the environment (including wastewater and groundwater).
- The production of many economically important industrial commodities relies on the exploitation of yeast and fungal metabolism and these include such diverse products as whole foods, food additives, fermented beverages, antibiotics, probiotics, pigments, pharmaceuticals, biofuels, enzymes, vitamins, organic and fatty acids, and sterols.

Introduction

In terms of human health, some yeasts and fungi represent major opportunistic life-threatening pathogens, while others are life-savers as they provide antimicrobial and chemotherapeutic agents. In modern biotechnology, several yeast species are being exploited as hosts for the expression of human therapeutic proteins following recombinant DNA and gene editing technologies

Introduction

Furthermore, an international synthetic biology research consortium, called Sc-2.0, has embarked on the construction of a completely synthetic version of Saccharomyces cerevisiae. This would represent the world's first fully synthetic eukaryotic genome! In addition to the direct industrial exploitation of yeasts and fungi, it is important to note that these organisms, most notably the yeast S. cerevisiae, play increasingly significant roles as model eukaryotic cells in furthering our fundamental knowledge of biological and biomedical science.

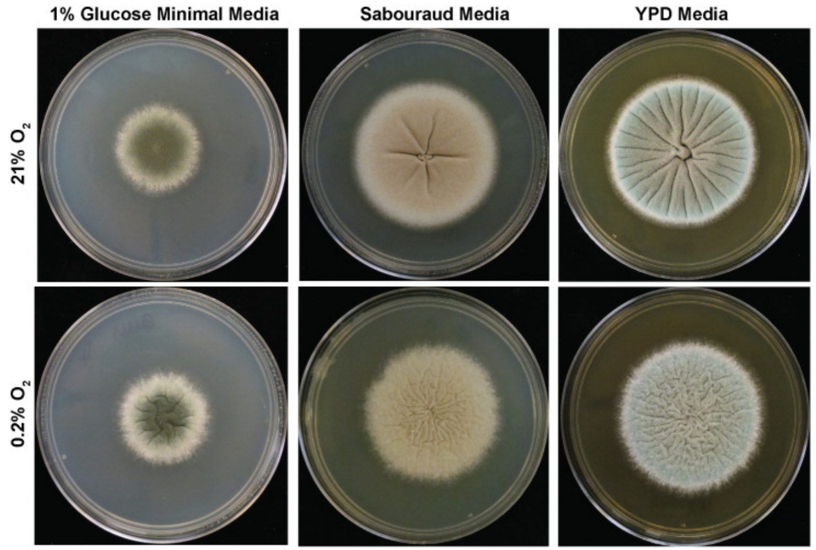


Introduction

This is especially the case now that numerous fungal genomes have been completely sequenced and the information gleaned from fungal genomics and proteomics is providing valuable insight into human genetics and heritable disorders. However, knowledge of cell physiology is essential if the functions of many of the currently unknown fungal genes, including "synthetic" ones, are to be fully elucidated.

Introduction

It is apparent, therefore, that fungi are important organisms for human society, health, and well-being, and that studies of fungal physiology are very pertinent to our understanding, control, and exploitation of this group of microorganisms. This chapter describes some basic aspects of fungal cell physiology, focusing primarily on nutrition, growth, and metabolism in unicellular yeasts and filamentous fungi.



Morphology of Yeasts and Fungi

There are a diversity of yeast and fungal cellular morphologies. Most higher fungi are filamentous, yeasts grow as unicells, and some primitive fungi such as the Chytridomycota grow as individual rounded cells or dichotomous branched chains of cells with root-like rhizoids for attachment to a nutrient resource. Here we consider the most common growth forms, the filamentous fungi and unicellular yeasts.

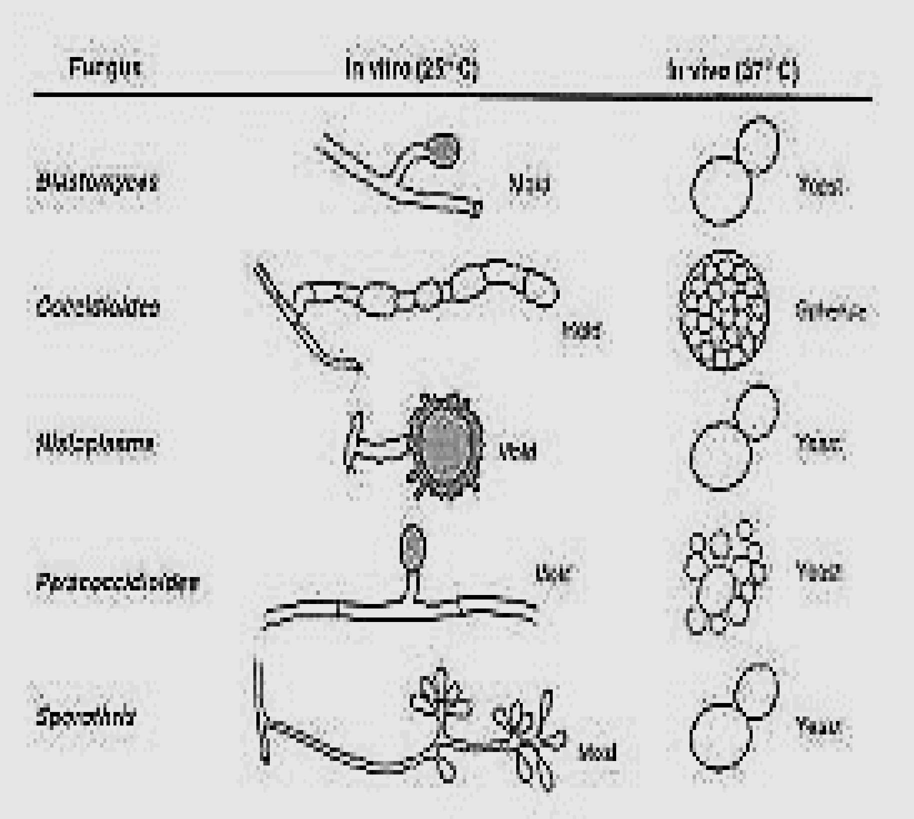
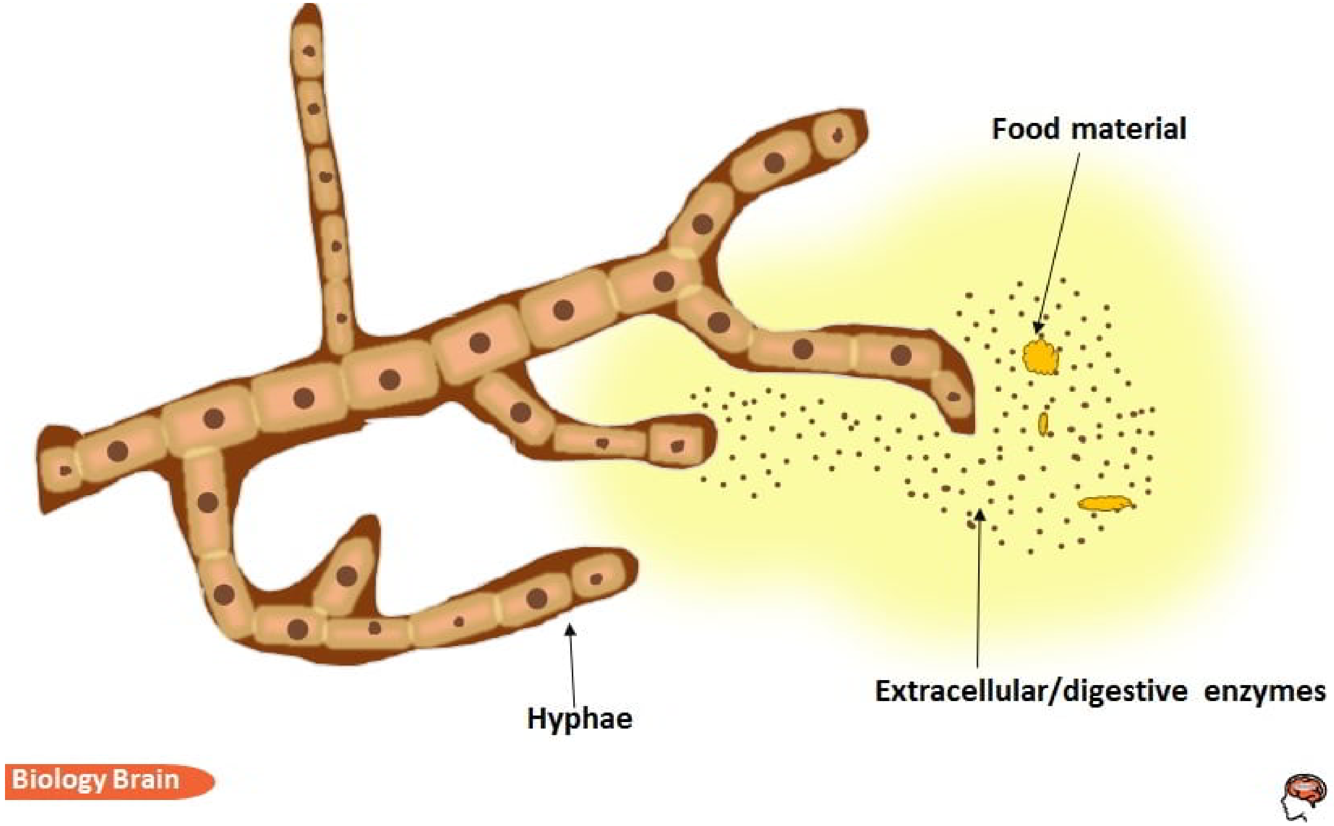


Table 1.1 Diversity of yeast cell shapes.

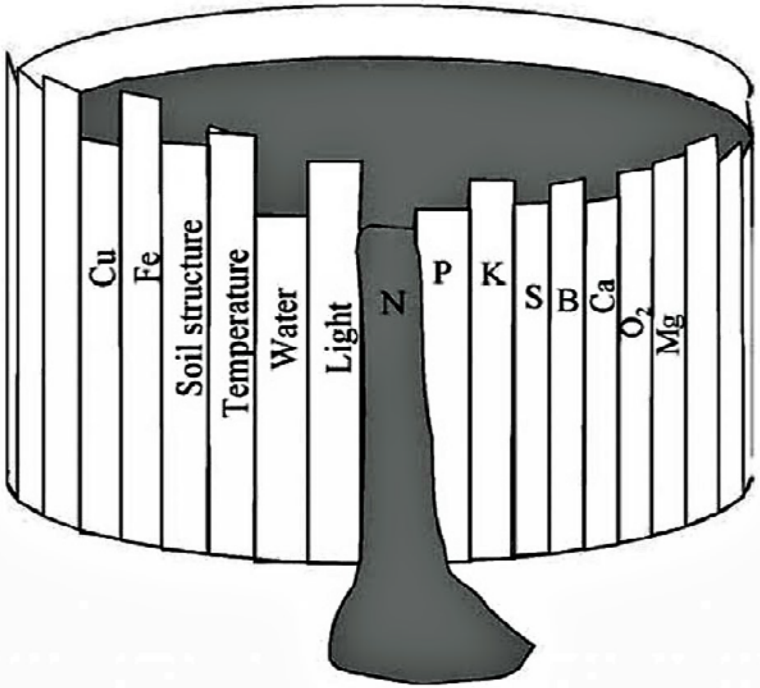
Cell shape	Description	Examples of yeast genera
Ellipsoid	Ovoid-shaped	*Saccharomyces*
Cylindrical	Elongated cells with hemispherical ends	*Schizosaccharomyces*
Apiculate	Lemon-shaped	*Hanseniaspora*, *Saccharomycodes*
Ogival	Elongated cell, rounded at one end and pointed at other	*Dekkera*, *Brettanomyces*
Flask-shaped	Cells divide by bud-fission	*Pityrosporum*
Miscellaneous shapes	Triangular	*Trigonopsis*
	Curved	*Cryptococcus* (e.g. *C. cereanus*)
	Spherical	*Debaryomyces*
	Stalked	*Sterigmatomyces*
Pseudohyphal	Chains of budding yeast cells which have elongated without detachment	*Candida* (e.g. *C. albicans*)
Hyphal	Branched or unbranched filamentous cells which form from germ tubes. Septa may be laid down by the continuously extending hyphal tip. Hyphae may give rise to blastospores	*Candida albicans*
Dimorphic	Yeasts that grow vegetatively in either yeast or filamentous (hyphal or pseudohyphal) form	*Candida albicans*, *Saccharomycopsis fibuligera*, *Kluyveromyces marxianus*, *Malassezia furfur*, *Yarrowia lipolytica*, *Histoplasma capsulatum*

Fungal Nutrition and Cellular Biosynthesis



1. Chemical requirements for growth

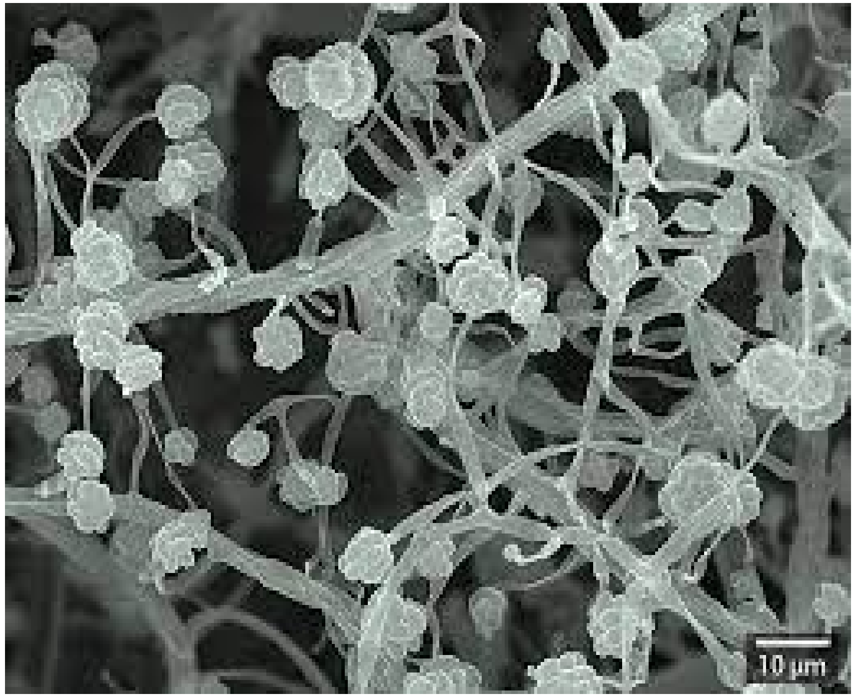
Yeasts and fungi have relatively simple nutritional needs and most species would be able to survive quite well in ***aerobic conditions*** if supplied with glucose, ammonium salts, inorganic ions and a few growth factors.



1. Chemical requirements for growth

1- **Macronutrients**, supplied at mill-molar concentrations, comprise sources of carbon, nitrogen, oxygen, Sulphur, phosphorus, potassium and magnesium

2- **Micronutrients**, supplied at micromolar concentrations, comprise trace elements such as calcium, copper, iron, manganese and zinc that would be required for fungal cell growth.



1. Chemical requirements for growth

Some fungi are oligotrophic, apparently growing with very limited nutrient supply, surviving by scavenging minute quantities of volatile organic compounds from the atmosphere.

1. Chemical requirements for growth

Being chemo-organotrophs, fungi need fixed forms of organic compounds for their carbon and energy supply. Sugars are widely utilized for fungal growth and can range from simple hexoses such as glucose to polysaccharides such as starch, cellulose and aromatic hydrocarbons (inc. lignin). The next table outlines the variety of carbon sources that can be utilized by yeasts and filamentous fungi for growth.

Table 1.4 Elemental requirements of fungal cells.

Element	Common sources	Cellular functions
Carbon	Sugars	Structural element of fungal cells in combination with hydrogen, oxygen, and nitrogen. Energy source
Hydrogen	Protons from acidic environments	Transmembrane proton motive force vital for fungal nutrition. Intracellular acidic pH (around 5–6) necessary for fungal metabolism
Oxygen	Air, O_2	Substrate for respiratory and other mixed-function oxidative enzymes. Essential for ergosterol and unsaturated fatty acid synthesis
Nitrogen	NH_4^+ salts, urea, amino acids	Structurally and functionally as organic amino nitrogen in proteins and enzymes
Phosphorus	Phosphates	Energy transduction, nucleic acid, and membrane structure
Potassium	K^+ salts	Ionic balance, enzyme activity
Magnesium	Mg^{2+} salts	Enzyme activity, cell and organelle structure
Sulfur	Sulfates, methionine	Sulfhydryl amino acids and vitamins
Calcium	Ca^{2+} salts	Possible second messenger in signal transduction
Copper	Cupric salts	Redox pigments
Iron	Ferric salts. Fe^{3+} is chelated by siderophores and released as Fe^{2+} within the cell	Heme-proteins, cytochromes
Manganese	Mn^{2+} salts	Enzyme activity
Zinc	Zn^{2+} salts	Enzyme activity
Nickel	Ni^{2+} salts	Urease activity
Molybdenum	Na_2MoO_4	Nitrate metabolism, vitamin B12

1. Chemical requirements for growth

Fungi are non-diazotrophic (cannot fix nitrogen) and need to be supplied with nitrogen-containing compounds, either in inorganic form such as ammonium salts, or in organic form such as amino acids. Ammonium sulphate is a commonly used nitrogen source in fungal growth media since it also provides a source of utilizable sulphur. Many fungi (but not the yeast S. cerevisiae) can also grow on nitrate, and if able to do so may also utilize nitrite. Nitrate reductase, followed by nitrite reductase, are the enzymes responsible for converting nitrate to ammonia.

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1. Chemical requirements for growth

- Most fungi can assimilate amino acids, amines and amides as nitrogen sources.

- Urea utilization is common in fungi and some basidiomycetous yeasts are classed as urease positive (able to utilize urea) whilst most ascomycetous yeasts are urease negative.

- In terms of oxygen requirements, most fungi are aerobes. Although yeasts such as S. cerevisiae are sometimes referred to as facultative anaerobes, they cannot grow in strictly anaerobic conditions unless supplied with certain fatty acids and sterols (which they cannot synthesize without molecular oxygen). For aerobically respiring yeasts and fungi, oxygen is required as the terminal electron acceptor. Different fungal species respond to oxygen availability in diverse ways.

1. Chemical requirements for growth

- Sulphur sources for fungal growth include sulphate, sulphite, thiosulphate, methionine and glutathione with inorganic sulphate and the sulphur amino acid methionine being effectively utilized. Virtually all yeasts can synthesize sulphur amino acids from sulphate, the most oxidized form of inorganic sulphur.

- Phosphorus is essential for biosynthesis of fungal nucleic acids, phospholipids, ATP and glycophosphates. Hence, the phosphate content of fungi is considerable (e.g. in yeast cells it accounts for around three to five percent of dry weight; the major part of this is in the form of orthophosphate ($H_2PO_4^-$), which acts as a substrate and enzyme effector). The fungal vacuole can serve as a storage site for phosphate in the form of polyphosphates. Both nitrogen and phosphorus availability may be growth limiting in nature. Filamentous fungi have evolved a number of biochemical and morphological strategies allowing capture of often poorly available phosphorus within the natural environment. Plants exploit such efficiency during symbioses between their roots and certain mycorrhizal fungi.

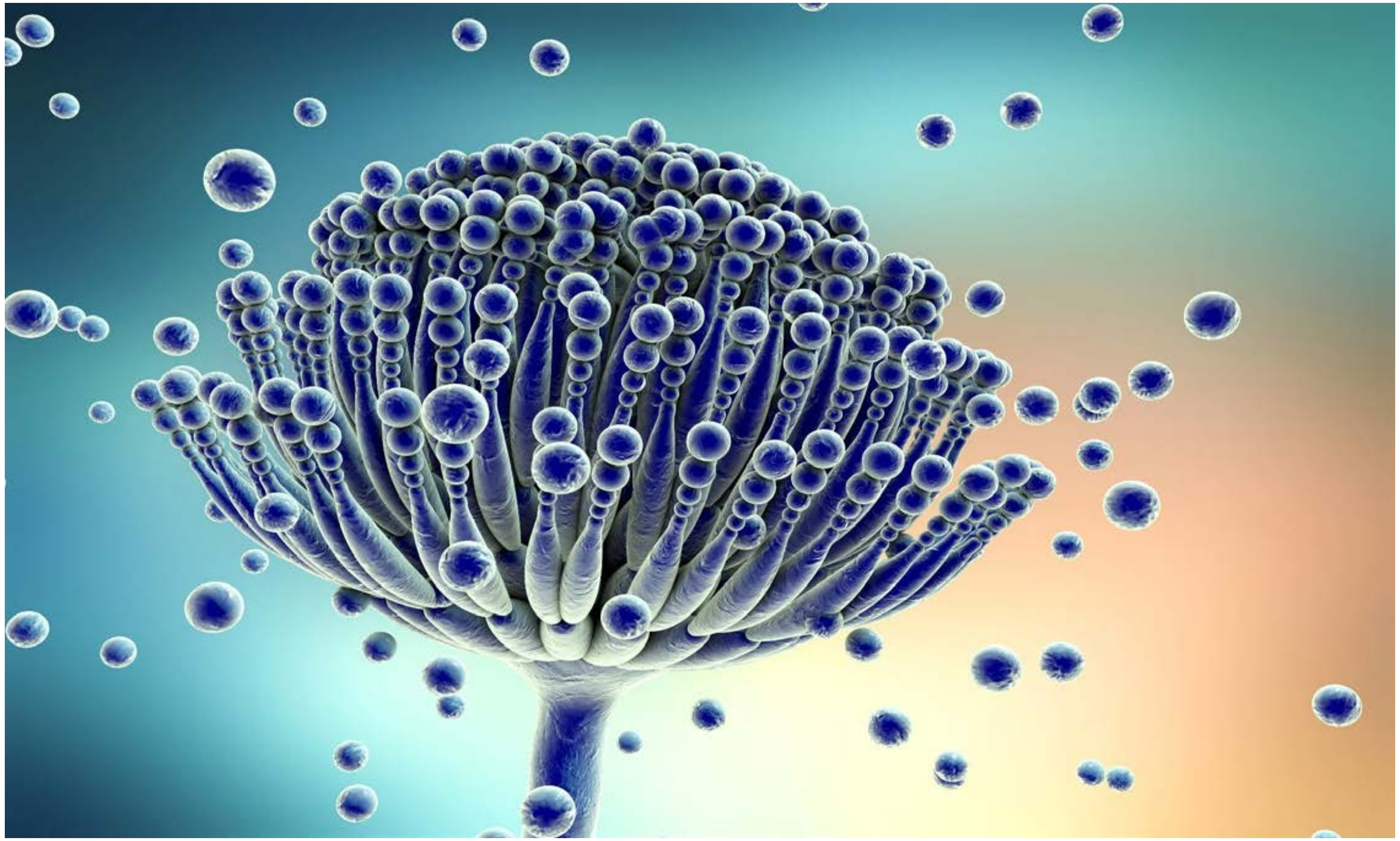
1. Chemical requirements for growth

- Concerning requirements for **minerals**, potassium, magnesium and several trace elements are necessary for fungal growth. K and Mg are macroelements required in millimolar concentrations whereas other microelements (trace elements) are generally required in the micromolar range. These include Mn, Ca, Fe, Zn, Cu, Ni, Co and Mo. Toxic minerals (e.g. Ag, As, Ba, Cs, Cd, Hg, Li and Pb) adversely affect fungal growth at concentrations greater than 100 mM.

Fungal growth factors

Fungal growth factors are organic compounds occasionally needed in very low concentrations for specific enzymatic or structural roles, but not as energy sources. These include vitamins (e.g. thiamin, biotin), purines, pyrimidines, nucleosides, nucleotides, amino acids, fatty acids and sterols. For fungi to have a growth factor requirement indicates that cells cannot synthesize the factor, resulting in the curtailment of growth without its provision in culture media. Some fungi (e.g. *Aspergillus niger* and *Penicillium chrysogenum*) have very simple nutritional needs and can synthesize their own growth factors from glucose.

2. Physical requirements for growth

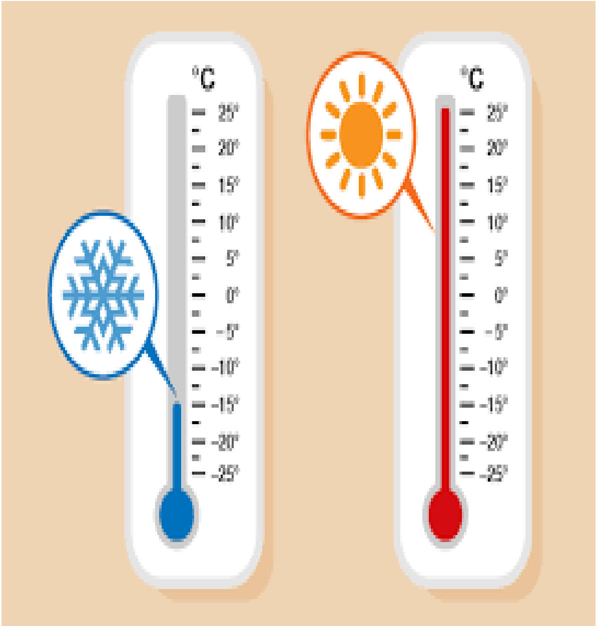


2. Physical requirements for growth

- Most yeast and fungal species thrive in warm, sugary, acidic and aerobic conditions.

1. Temperature

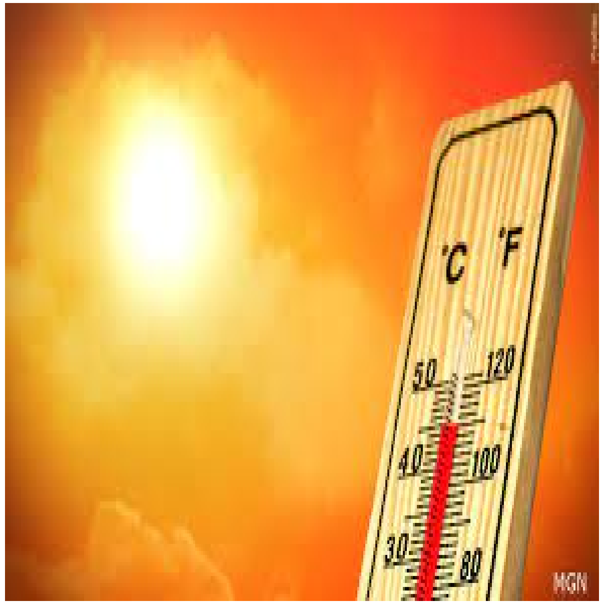
The range of temperature for fungal growth is quite wide, but most species grow very well around 25 °C. Low-temperature psychrophilic fungi and high-temperature thermophilic fungi do, however, exist in nature. Fungal growth at various temperatures depends not only on the genetic background of the species but also on other prevailing physical growth parameters and nutrient availability. About high-temperature stress on fungal cells, thermal damage can disrupt hydrogen bonding and hydrophobic interactions, leading to general denaturation of proteins and nucleic acids.



2. Physical requirements for growth

1. Temperature

Fungi, of course, have no means of regulating their internal temperature, and the higher the temperature the greater the cellular damage, with cell viability declining when temperatures increases beyond growth-optimal levels. Temperature optima vary greatly in fungi, with those termed 'thermotolerant' growing well above 40°C. Thermotolerance relates to the transient ability of cells subjected to high temperatures to survive subsequent lethal exposures to elevated temperatures, such that *intrinsic* thermotolerance is observed following a sudden heat shock (e.g. to 50 °C)



2. Physical requirements for growth

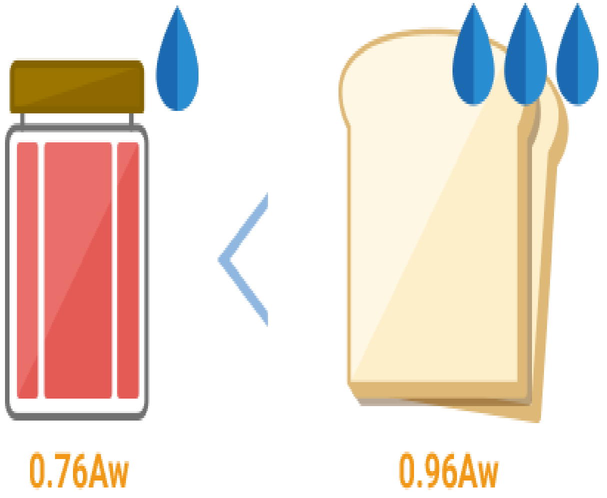
1. Temperature

whereas induced thermo tolerance occurs when cells are pre-conditioned by exposure to a mild heat shock (e.g. 30 minutes at 37 °C) prior to a more severe heat shock. Heat-shock responses in fungi occur when cells are rapidly shifted to elevated temperature and, if this is sub-lethal, induced synthesis of a specific set of proteins, the highly conserved 'heat-shock proteins' (Hsps), occurs. Hsps play numerous physiological roles, including thermo protection

2. Physical requirements for growth

2. Water activity (aw)

- High water activity is required for growth of most fungi, with a minimum aw of around 0.65. Water is essential for fungal metabolism, and any external conditions that result in reduced water availability to cells (i.e. water stress') will adversely affect cell physiology.
- The term water potential refers to the potential energy of water and closely relates to the osmotic pressure of fungal growth media. Species such as Zygosaccharomyces rouxii and some Aspergillus species able to grow in low-water-potential conditions (i.e. high sugar or salt concentrations) are referred to as osmotolerant or zerotolerant. S. cerevisiae is described as non-osmotolerant yeast



2. Physical requirements for growth

2. Water activity (aw)

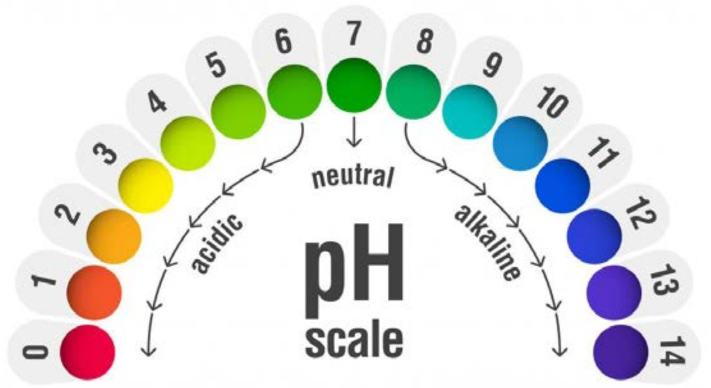
- Mild water stress, or hypersomotic shock, occurs in fungi when cells are placed in a medium with low water potential brought about by increasing the solute (e.g. salt, sugar) concentration. Conversely, cells experience a hypo-osmotic shock when introduced to a medium of higher osmotic potential (due to reducing the solute concentration).

- Fungi are generally able to survive such short-term shocks by altering their internal osmotic potential (e.g. by reducing intracellular levels of K+ or glycerol). Glycerol is an example of a compatible solute that is synthesized to maintain low cytosolic water activity when the external solute concentration is high

2. Physical requirements for growth

3. pH

- Most fungi are acidophilic and grow well between pH 4 and 6, but many species can grow, albeit to a lesser extent, in more acidic or alkaline conditions (around pH 3 or pH 8, respectively). Fungal cultivation media acidified with organic acids (e.g. acetic, lactic acids) are more inhibitory to yeast growth compared with those acidified with mineral acids (e.g. hydrochloric, phosphoric acids) because organic acids can lower intracellular pH (following their translocation across fungal plasma membranes).



2. Physical requirements for growth

4. Other physical parameters

- There are many parameters influencing fungal physiology include radiation (light or UV may elicit mycelial differentiation and sporulation in some fungi that produce airborne spores), aeration, pressure, centrifugal force and mechanical shear stress.

Nutrient uptake and assimilation

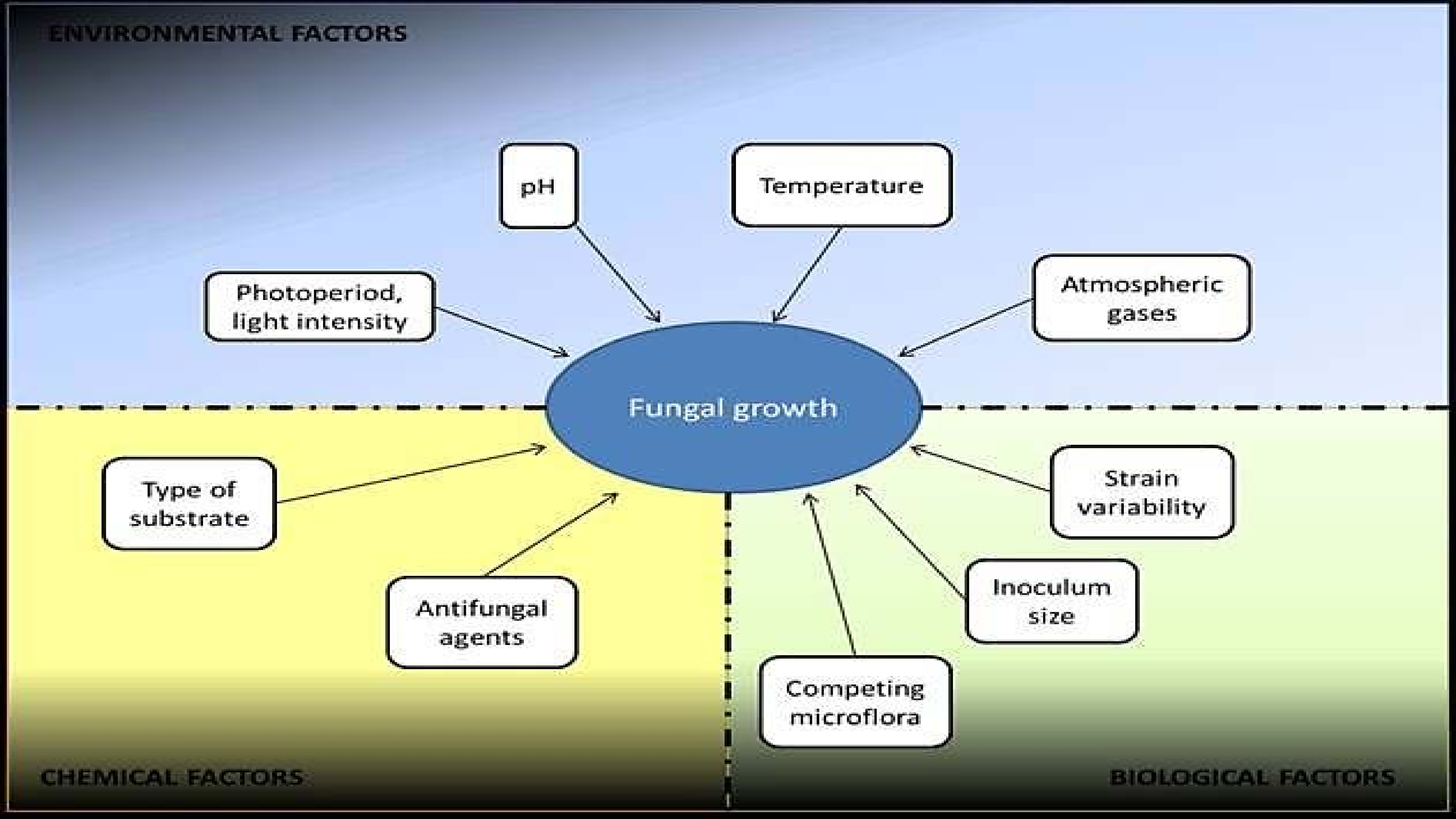
- Fungal cells utilize a diverse range of nutrients and employ equally diverse nutrient acquisition strategies. Fungi are non-motile, saprophytic (and sometimes parasitic), chemo-organotrophic organisms. Fungi exhibit dynamic interactions with their nutritional environment that may be exemplified by certain morphological changes depending on nutrient availability. For example, the filamentous mode of growth observed at the periphery of yeast colonies growing in agar is akin to a foraging for nutrients as observed in certain eucarpic fungi.
- Metabolic dynamism is also evident in yeasts, which, although not avid secretors of hydrolytic enzymes like higher filamentous fungi, are nevertheless able to secrete enzymes to degrade polymers such as starch (amylolytic yeasts)

Nutrient uptake and assimilation

- Several cellular envelope barriers to nutrient uptake by fungal cells exist, namely the capsule, the cell wall, the periplasm and the cell membrane. Although not considered as freely porous structures, fungal cell walls are relatively porous to molecules up to an average molecular mass of around 300Da, and will generally retain molecules greater than around 700 Da. Generally, fungi can absorb only small soluble nutrients (monosaccharides, amino acids or small peptides).
- The plasma membrane is the major selectively permeable barrier that dictates nutrient entry and metabolite exit from the fungal cell. Membrane transport mechanisms are important in fungal physiology since they govern the rates at which cells metabolize, grow and divide. Fungi possess different modes of active and passive uptake at the plasma membrane: -

Nutrient uptake and assimilation

- **1- Active transport**: is the movement of a substance across a plasma membrane against its concentration gradient (from low to high concentration) Active transport of nutrients such as sugars, amino acids, nitrate, ammonium, sulphate and phosphate in filamentous fungi involves spatial separation of the ion pumps mostly behind the apex, whereas the symport proteins are active close to the tip. Thus, nutrient uptake occurs at the hyphal tip as it continuously drives into fresh resource, and the mitochondria localized behind the apex supply ATP to support the ion pump.
- **2- Passive transport**, unlike active transport, it does not require chemical energy. The rate of passive transport depends on the permeability of the cell membrane which, in turn depends on the organization and characteristics of the membrane lipids and proteins. free diffusion, facilitated diffusion, diffusion channels are consider kinds from passive transport.


ENVIRONMENTAL FACTORS
pH
Temperature
Photoperiod, light intensity
Atmospheric gases
Fungal growth
Type of substrate
Antifungal agents
Strain variability
Inoculum size
Competing microflora
CHEMICAL FACTORS
BIOLOGICAL FACTORS

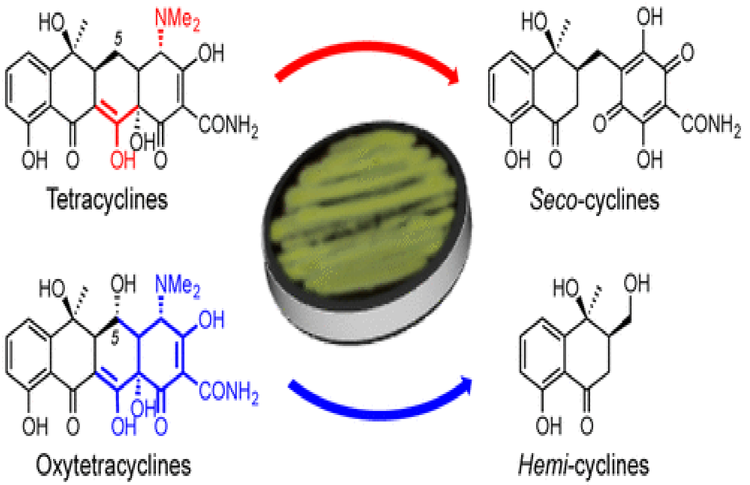
Commercial fungal products

Commercial fungal products

- Yeast plays a central role in the manufacture of bread. In this case the dough is infused with *Saccharomyces cerevisiae* and aerated. The dough is left to stand for a short period in a warm environment.
- during which time yeast cell respiration occurs and carbon dioxide is produced. Respiration can be summarized by the following equation:
- $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ΔG^o(respiration) = -686kcal/mol
- The production of carbon dioxide gives bread its light, airy quality. While baking is essentially an aerobic process, some semi-anaerobic conditions develop in the dough and ethanol can be produced in small amounts. This, together with the carbon dioxide, is burnt off during the baking process and gives rise to the "fruity smell" often associated with bakeries. In some parts of Japan bread dough is left to stand for a few days, during which the oxygen is used up in respiration and fermentation commences. The dough soon contains appreciable levels of ethanol and is subsequently eaten!

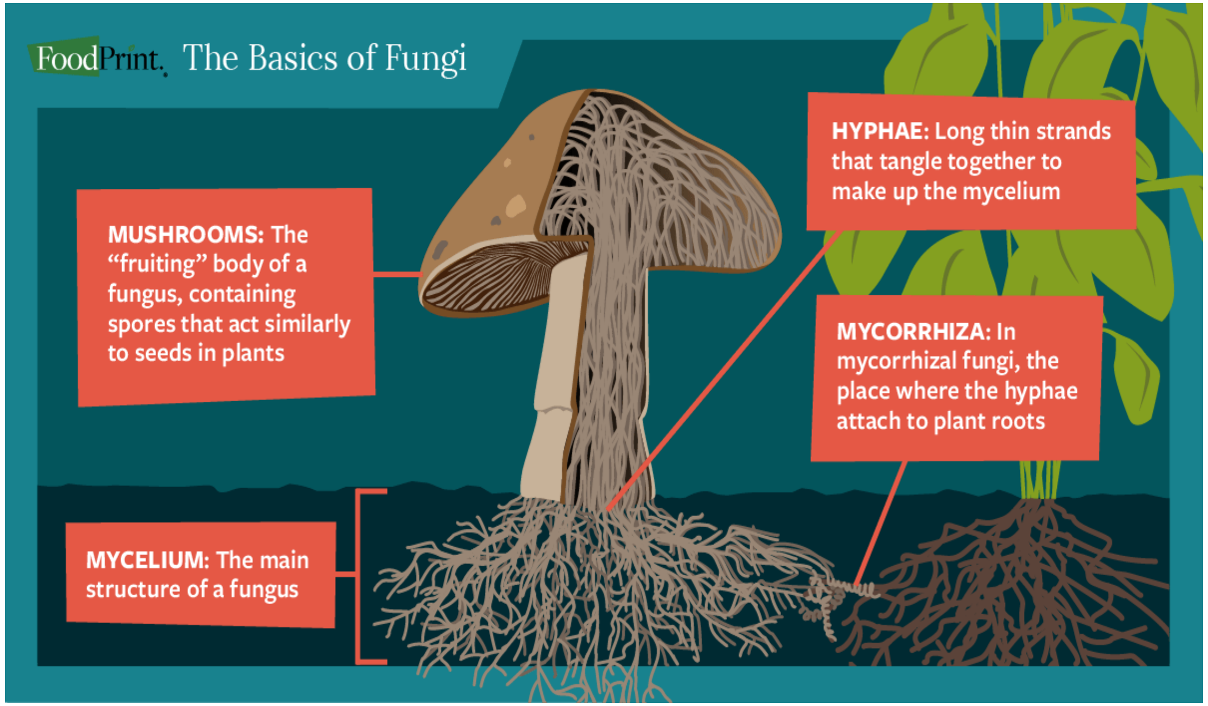
Antibiotics, Enzymes and Chemical Commodities from Fungi

- fungi have been exploited to yield a range of important products, some of which have proved invaluable to mankind. Since the time of the Pharaohs, fungi have been utilized for simple food processing; however, the last century has seen the development of fungal biotechnology for the subsequent production of valuable commodities such as antibiotics, enzymes, vitamins, pharmaceutical compounds, fungicides, plant growth regulators, hormones and proteins.



Class of product	Typical example	Industrial/commercial_application	Common production organism
Enzymes	Amylase	Starch processing Fermentation application	Aspergillus niger Rhizopus oryzae
	Cellulase	Animal feed industry Brewing	Trichoderma longibrachiatum
	Protease	Meat/leather industry, Cheese manufacture	Aspergillus oryzae, Rhizopus oligosporus
Organic acid	Citric acid Itaconic acid Malic acid Fumaric acid	Soft drinks industry Chemical industry Beverage/food industry Food industry	Aspergillus niger Candida/Rhodoturula Candida Candida
Vitamins	Riboflavin Pyridoxine D-erythro-ascorbic acid	Health industry Health industry Health industry	Candida Pichia Candida
Antibiotics	Penicillin Cephalosporin	Human/animal health Human/animal health	Penicillium chrysogenum Cephalosporium acremonium
Fatty acids	Stearic Dicarboxylic	Food industry Chemical industry	Cryptococcus Candida
Alcohol	Industrial alcohol Beverage alcohol	Fuel industry Beverage industry	Saccharomyces Saccharomyces
Pharmaceuticals	Lovastatin Cyclosporin	Human health Human health	Monascus rubber Tolypocladium inflatum
Amino acids	Lysine Tryptophan	Health industry Health industry	Saccharomyces Hansenula

Fungal metabolism



Fungal metabolism

- A common link between all fungi is their heterotrophic nature: they cannot manufacture their own food and depend on the organic material in other organisms for their survival. In a broad sense, however, it is possible to ascribe fungi into two main groups depending on how they obtain and assimilate nutrients.

- 1- **One group**, the parasitic and mutualistic symbionts, obtains its nutrients in an effective manner from living organisms.

- **2-The second group**, saprotrophs, has the ability to convert organic matter from dead organisms into the essential nutrients required to support growth. It is this second group that we are particularly interested in, as this group of organisms gives rise to the production of the main bulk of the commodities commonly associated with fungi. However, regardless of this division, within the fungal life cycle one can clearly delineate the production of certain products or metabolites into two phases, namely primary and secondary metabolism.

- 1- Primary metabolites are those that are essential for growth to occur and include proteins, carbohydrates, nucleic acids and lipids. Indeed, the precursors of these primary products must be synthesized if they cannot be obtained from the growth medium. These primary metabolites have essential and obvious roles to play in the growth of the fungus.
- Typically, primary metabolites are associated with the rapid initial growth phase of the organism and maximal production occurs near the end of this phase. Once the fungus enters the stationary phase of growth, however, primary metabolites may be further metabolized.
- Examples of primary metabolites produced in abundance include enzymes, fats, alcohol, and organic acids. Economically speaking, primary metabolites are easily exploited as the biochemical pathways involved in their production are widespread throughout the fungal kingdom. This allows for the rapid screening of classes of fungi for such products and the rapid development of production processes for their utilization.
- Primary metabolic processes have also been extensively usurped through the use of recombinant DNA technologies, to the extent that heterologous proteins can be routinely produced by the host fungus as part of its primary metabolic phase.

Fungal metabolism

- 2- Secondary metabolites are not essential for vegetative growth and indeed may have little or no primary function within the organism. Secondary metabolites are produced when the organism enters the stationary phase, once the initial phase of rapid growth has declined. The metabolites produced in this phase are often associated with differentiation and sporulation and can have profound biological activities, which in some instances have been exploited economically.
- A number of distinct differences are apparent between primary and secondary metabolites. In the first instance, they have been shown to possess an enormous variety of biosynthetic origins and structures that are not, in general, found among the primary metabolites.
- Secondly, their occurrence tends to be restricted to a small number of organisms and indeed can vary between individual strains of the same species.

Fungal metabolism

- Finally, their production is characterized by the generation of groups of closely related compounds, which may have very different biological properties. Important examples of secondary metabolites include medically important compounds such as antibiotics, statins, cyclosporins, and ergot alkaloids. Agriculturally important secondary metabolites include strobilirubin, an antifungal compound, and plant hormones such as giberellic acid. Fungal biotechnology has developed, to allow the utilization of the metabolic processes inherent to the organisms, in a commercially viable manner.

Metabolites	Example	Production organism
Primary metabolites	Enzymes Industrial alcohol Organic acids Fats Polymers	Aspergillus sp. Saccharomyces cerevisiae Aspergillus/Candida Candida Yarrowia
Secondary metabolites	Antibiotics: Penicillin Fusidic acid	 Penicillium Fusidium coccineum
	Cholesterol lowering agents: Lovastatin Mevastatin	 Monascus rubber Penecillium citrinum
	Immunosuppressing drugs: Cyclosporin A	 Tolypocladium inflatum
	Plant hormones: Giberellic acid	 Gibberella fujikuroi

Antibiotic production

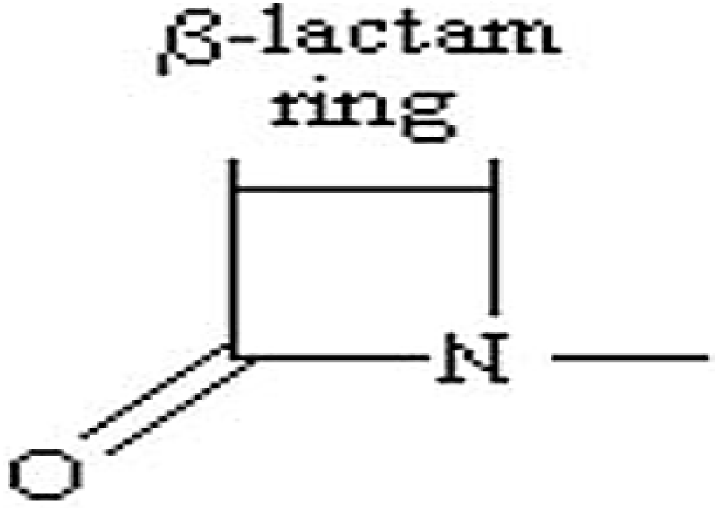
Overview

- The most studied secondary metabolites are a class of compounds known as antibiotics. These low-molecular-mass compounds are so-called because at low concentrations they inhibit the growth of other micro-organisms. While many thousands of antibiotics have been discovered, their use has been limited to perhaps 60 at most due to the toxic properties they exhibit toward humans.

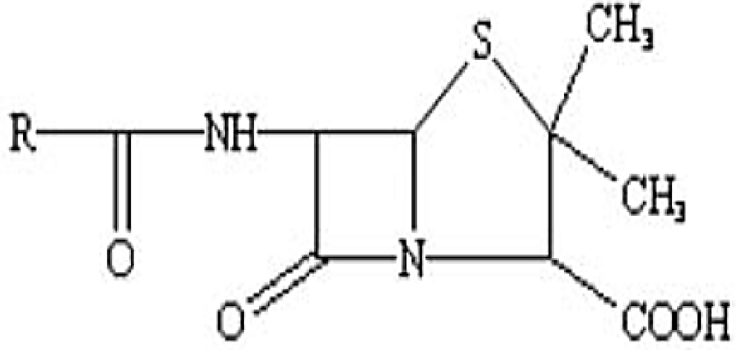
- Clinically speaking the majority of antibiotics are produced by the Actinomycetes, a bacterial order, and will not be dealt with here. Whilst several fungal genera produce antibiotics, only two do so to a commercially viable extent, *Aspergillus* and *Penicillium*. The b-lactams, of which penicillin is the most famous, not least because of its fortuitous discovery by Fleming in 1928, comprise a very large group of antibiotics and include both cephalosporins and penicillins. In 2000 the estimated world market for antibiotics was $28 billion, which underlies the importance both medically and economically of these metabolites.

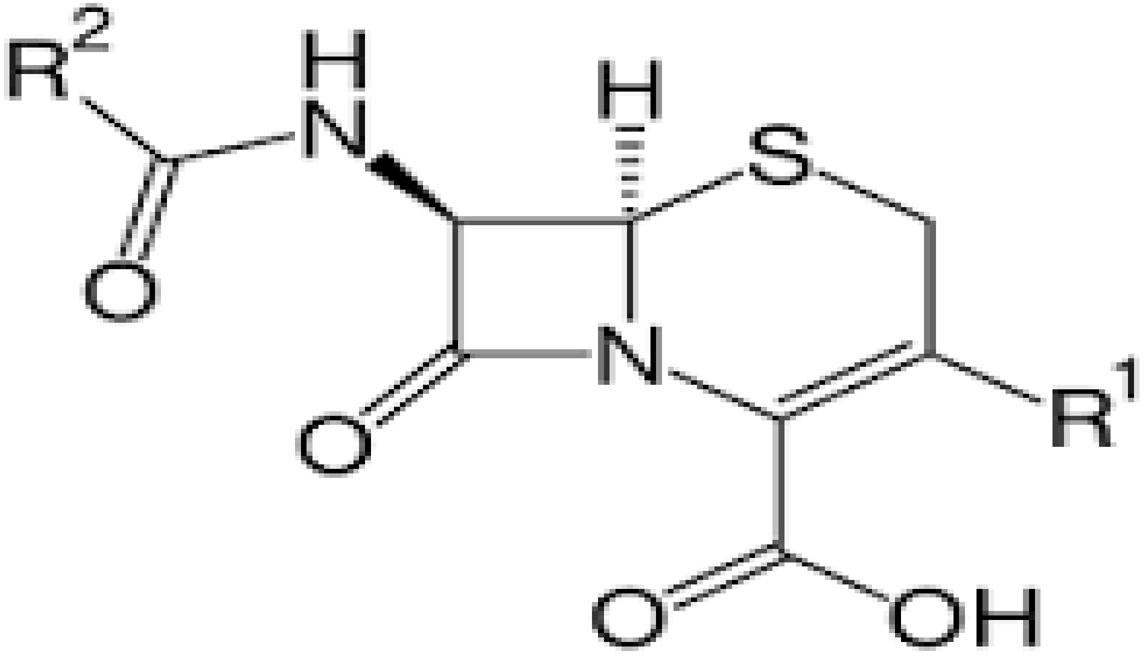
Overview

- The word penicillin can be regarded as a generic term used to describe a large group of natural and semi-synthetic antibiotics that differ only by the structure of the side chains on the core aminopenicillanic acid ring. As a rule, the basic penicillin molecule consists of a b-lactam ring, a five-membered thiazolidine ring, and a side chain. b-lactams with non-polar side chains such as phenylacetate and phenoxy acetate are hydrophobic in nature and include penicillin G (benzylpenicillin) and penicillin V (methylpenicillin). The non-polar penicillins are synthesized only by filamentous fungi.
- At their core, they all possess a b-lactam (four-atom cyclic amide) ring on which side-chain substitutions and differences give rise to a series of antibiotics each with differing anti-bacterial activity. In addition to the so-called classical b-lactams, semi-synthetic varieties can be manufactured by the removal of the naturally occurring side chains and the subsequent chemical derivitization of the core b-lactam ring.



Penicillin structure





Cephalosporin structure

Overview

- The cephalosporins are a class of β-lactam antibiotics originally derived from the fungus Acremonium, which was previously known as "Cephalosporium". Together with cephamycins, they constitute a subgroup of β-lactam antibiotics called cephems. Cephalosporins were discovered in 1945, and first sold in 1964

- Gram positive bacteria possess on the outer aspect of the cell wall a layer that is composed of characteristic groupings of proteins and carbohydrates that comprise the antigenic determinants responsible for generating an immune response. Inside this outermost layer there is a polymeric structural layer known as peptidoglycan which is composed of repeating units of N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM).

- Associated with this cell wall structure are a number of proteins known as penicillin-binding proteins (PBP); the function of some is unclear. During cell wall biosynthesis, a cross-linking process occurs, whereby peptidoglycan strands become linked, leading to the structural stability of the wall. It is this cross-linking that is extremely sensitive to b-lactam antibiotics. For instance, various penicillins bind to the PBPs through their different side-chains, leading to a variety of effects

Overview

- Reaction with PBP-1 (a transpeptidase) produces cell lysis, while binding to PBP-2 (also a transpeptidase) leads to the generation of oval cells, which are unable to replicate. Cephalosporins act in a very similar fashion to the penicillins and are also able to react with the PBPs by forming covalent bonds, thus leading to cellular lysis.
- Gram negative cells have a more complex cell wall structure and usually contain an outer membrane and a complex periplasm containing lipopolysaccharides. Whilst the gram negative cell wall also contains a peptidoglycan layer, it is not as extensive as that of gram positive bacteria but is sensitive to b-lactam antibiotics due to the presence of PBPs.

Overview

- **Penicillins** with polar side chains, such as D-a-aminoadipate, include penicillin N and possess hydrophilic characteristics. They are more widely synthesized by a range of micro-organisms, including fungi, actinomycetes and unicellular bacteria.

Important fungal diseases

1. Stem rust of wheat disease

- **The pathogen: *Puccinia graminis***

➢ Symptoms on cereal crops:

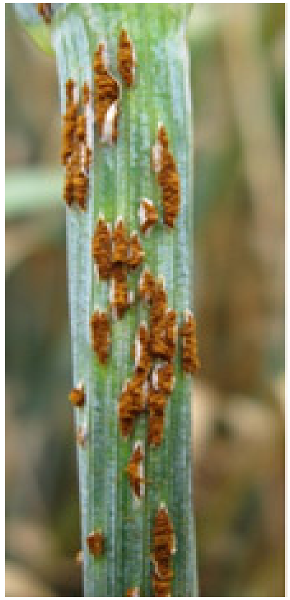
- The appearance of narrow longitudinal blotch parallels the main veins
- At the last phase of infection, the symptoms transfer to hill envelops
- After days epidermis which covers with blotch ruptured and go out a red powder that resembles uredospore
- In the last season, the blotch color turns black due to forming telliospores

1. Stem rust of wheat disease

- **The pathogen: *Puccinia graminis***

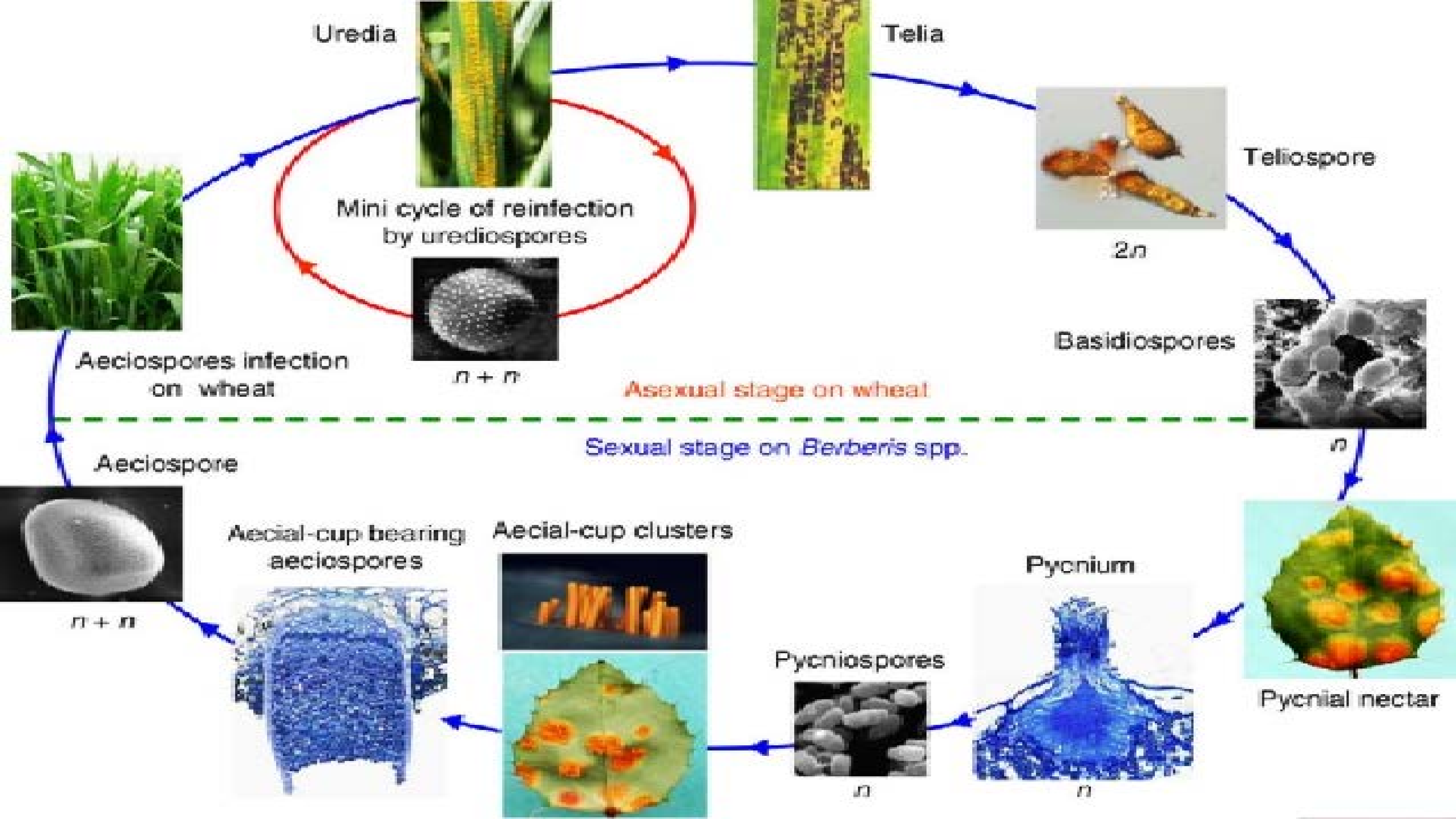
➢ Symptoms on cereal crops:

- The appearance of yellow or orange spots on the upper surface of leaves, fruits, and shoots.
- In these spots, there are dark microbodies known as pycnidia or spermatogonia
- The appearance of yellow-orange known as aecia.



Disease cycle

- Under suitable conditions (in the spring).
- The teliospores present in infected plants germinate and form basidiospores
- Basidiospores dispersed by win until reach the host cell (barberry plant) germinate and penetrate directly epidermis cell
- Then germinate and forms mycelium which forms haustoria in the cell
- Mycelium forms a mass of hypha under the epidermis layer known as spermagonia which has a dark color
- When the epidermis is ruptured, spermagonia produce hypha which knows as (receptive hyphae) which are female organs.
- Under this hypha (receptive hyphae) spermatia are found which is (male organs) spermatia are found which is (male organs) which contain pycnidiospores
- Which transfer by wine water or insect to leaves contain receptive hyphae then fertilization occurs and forms the mother aecial cell which produces aeciospores


Uredia
Telia
Teliospore
2n
Mini cycle of reinfection
by urediospores
n + n
Basidiospores
n
Aeciospores infection
on wheat
Asexual stage on wheat
Sexual stage on Berberis spp.
Aeciospore
n + n
Aecial-cup bearing
aeciospores
Aecial-cup clusters
Pycnium
n
Pycniospores
n
Pycnial nectar

Control

By using of

- Dichlrone
- Zineb
- Oxycarboxin

2. Apple scab disease

- **The pathogen: *Venturia inaequalis***

➢ Symptoms:

- Appearance irregular spots on the lower surface of young leaves to flower buds, these spot has olive green color, after that, it becomes globose and dark green.
- The color of general surface leaves is black gray.
- At strong infection increase the number of spots and decrease the size of leaves, which furl gradually, these leaves fall.
- Appearance of scabby globular regions which velvet in infected fruit and color of these infected regions become black.
- Early infection of fruits, this infection leads to deformation of shape of fruits, these fruits fall.

Disease cycle

Disease cycle

- *At the spring (suitable conditions) the old infected leaves are saturated with water, asci will from it which contain ascospores
- *Ascospoes release from asci, when ascospores reach to host cell (by water or win) germinate and form micro hypha tube
- * Microhypha tube penetrates the cuticle, and cell wall of the epidermis, after that it germinates forming mycelium
- * Mycellium absorb nutrients and germinate to form conidiophores which form ascospores
- * Ascospores are released and repeat the infection under suitable conditions

Control

Control

- By using of dodine and captin, fixed copper, Bordeaux mixtures, copper soaps (cpper octanoare), sulfur, mineral or neem oils, and myclobutanil.

3. Loose smut of cereals

The pathogen: *Ustilago nuda, U. tritici*

➢ **Symptoms:**

1- The hills become smut, without grains or other flowery parts except the main axis which is covered by density black powder (telliospores)

2- At development the infection , the hill usually covered by spores are released by win ,the hill axis become naked.

3. Loose smut of cereals

The pathogen: *Ustilago nuda, U. tritici*

➢ Symptoms:

3- The level of infected hill is higher than the level of healthy hill.

➢ Disease cycle

At cultivation of infected seed (mycelium of fungus present inside the seed) and under suitable condition

The mycelium germinate and grow between embryo cell or seeding until reach to the top of plant.

3. Loose smut of cereals

When the plant form hills mycelium invaded the hills and destroyed the tissue except axis

Telloispores are formed which surrounded by the membrane

At mature the thin membrane is ruptured and the telliospores is released.

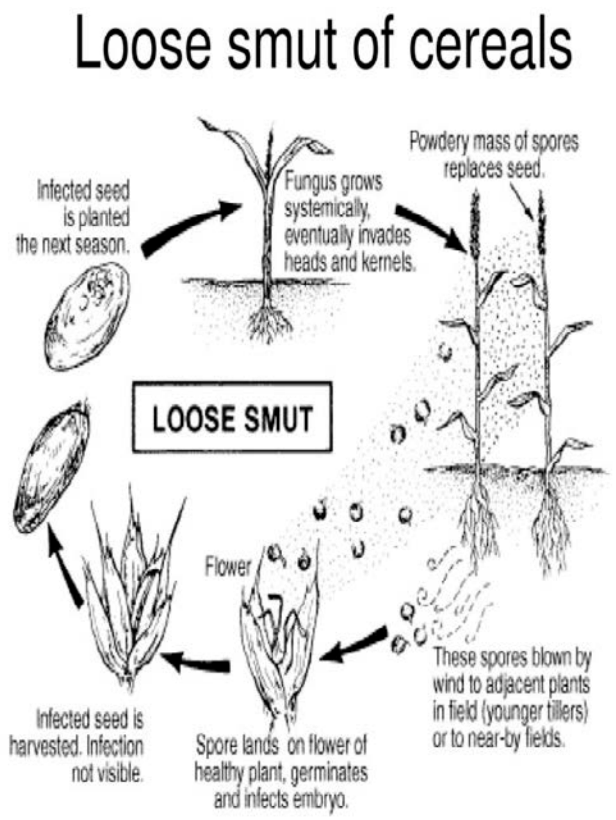
The telliospores is drop on other plants and infected during flowering stage and germinate on flower to form (basidial body)which haploid hypha

Then the fusion occur between two haploid hypha to form mycelium diploid (2 n)

3. Loose smut of cereals

Mycelium penetrate wall of ovary and fixed in wall of fruit, sheet of seed and finally in tissue of embryo before grain become mature

The mycelium become dormant until cultivation of infected seeds, which at suitable condition grow and repeat the cycle.



3. Loose smut of cereals

Control

By using of carboxin and 1,4-oxanthin

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