

With the kind support of

syngenta



Department of Plant Pathology, Christian-Albrechts University, Kiel
Prof. Dr. Joseph-Alexander Verreet, Dr. Holger Klink (eds.)

THE BIOLOGY OF FUNGAL PATHOGENS

2

In-depth knowledge of the conditions under which pathogens, in particular parasitic fungi, live and develop is a prerequisite for crop protection. The video series "The Biology of Fungal Pathogens" grants easy access to this knowledge. Through an exciting blend of vivid 3D animations and real images, with informative commentaries, these videos provide a fascinating insight into the life cycles of major fungal pathogens. The series is an outstanding example of communication in modern science.

Editors-in-Chief and Scientific Advisors:

Prof. Dr. Joseph-Alexander Verreet, Dr. Holger Klink
Department of Plant Pathology,
Christian-Albrechts University, Kiel
Hermann-Rodewald-Str. 9, D-24118 Kiel, Germany
Phone: +49.431.880.2996 or +49.431.880.4586
Fax: +49.431.880.1583
E-mail: javerreet@phytomed.uni-kiel.de
or: hklink@phytomed.uni-kiel.de

Scientific Advisors (Fusarium Diseases):

Prof. Dr. Heinz-Wilhelm Dehne,
Dr. Erich-Christian Oerke, Dr. Ulrike Steiner,
Institute for Plant Diseases, University of Bonn
Nussallee 9, D-53115 Bonn, Germany
Phone: +49.228.73.3341; Fax: +49.228.73.3342
E-mail: hw-dehne@uni-bonn.de
or: ec-oerke@uni-bonn.de, or: u-steiner@uni-bonn.de

Video Production and Design:

STUMM-FILM Dr. Rolf Stumm Medien GmbH
Martin-Luther-Str.55, D-71636 Ludwigsburg, Germany
E-mail: info@stummfilm.de – www.stummfilm.de

Reordering Address:

The American Phytopathological Society
3340 Pilot Knob Road
St. Paul, Minnesota 55121-2097
United States of America
Phone: +1.651.454.7250; Fax: +1.651.454.0766
Web Site: www.apsnet.org

Target groups:

Students, farmers, technical advisors, teachers

Already published:

Vol. 1: Fungal Pathogens and Diseases of Cereals (3 videos).

Available on DVD and VHS video cassette

With the kind support of
Stiftung Schleswig-Holsteinische Landschaft

© 2003

Institut für Phytopathologie der Christian-Albrechts-Universität Kiel and STUMM-FILM Dr. Rolf Stumm Medien GmbH

All rights reserved.
Reprinting in whole or in part is prohibited.



Vol. 2: Fungal Pathogens and Diseases of Cereals (2)



2.1

Leaf Rust and Other Rusts of Cereals



2.2

Fusarium Diseases of Wheat

In Collaboration with:
Prof. Dr. Heinz-W. Dehne,
Dr. Erich-C. Oerke,
Dr. Ulrike Steiner,
Institute for Plant Diseases,
University of Bonn



Plant pathology is a discipline devoted to maintaining plant health and, by so doing, helping to ensure economically and ecologically sound production of foodstuffs in sufficient quantities and of high quality. This places great demands on the effectiveness of research. It also presupposes in-depth knowledge of many aspects of both abiotic and biotic pathogens (e.g. fungi, bacteria, viruses, animal pests) and of plant protection.

Teaching is therefore of great importance. One especially interesting aspect of it is the transfer of knowledge of the sometimes very complex biological relationships in the life or development cycles of pathogenic organisms – host-parasite relationships which run their course under prevailing plant cultivation and environmental conditions.

The video series “The Biology of Fungal Pathogens” employs state-of-the-art visualization methods to illustrate the life cycles of various fungal pathogens. The combination of vivid 3D computer animations with real images results in a realistic overall picture that helps the viewer to understand the bio-ecological aspects of host-parasite relationships.

This new information medium addresses both specialist and lay audiences. The target group includes teachers and students at many types of educational institutions, university lecturers, students of agronomy, biology, ecology and their related disciplines, as well as governmental and non-governmental advisory bodies and, last not least, farmers.

Thanks are due to Dr. Heinz-W. Dehne, Dr. Erich-C. Oerke, and Dr. Ulrike Steiner of University of Bonn who contributed their expert knowledge to the movie on Fusarium diseases of wheat.

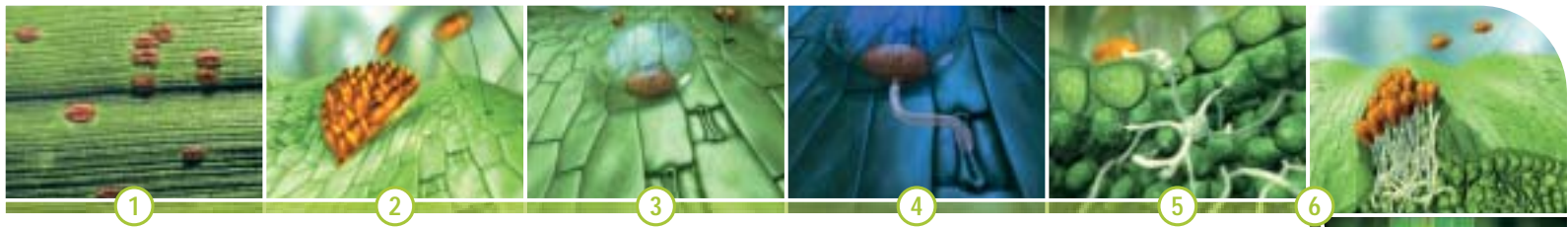
We are deeply indebted to Dr. Randy C. Ploetz, Editor-in-Chief of APS Press, University of Florida, the APS Press staff, and Dr. Thomas J. Baum of Iowa State University for their editorial assistance and dedicated support in bringing this project to a successful conclusion.

We owe a special debt of thanks to Syngenta Agro GmbH (Germany) and to Stiftung Schleswig-Holsteinische Landschaft for their generous support of this project.

Joseph-Alexander Verreet

Holger Klink

Video Series “The Biology of Fungal Pathogens”	
Vol. 2: Fungal Pathogens and Diseases of Cereals (2)	Pages
2.1 Leaf Rust and Other Rusts of Cereals (15:30 min)	4–5
Using leaf or brown rust of wheat (<i>Puccinia recondita</i> f.sp. <i>tritici</i>) as an example, this movie depicts the complete life cycle of rust fungi with exhaustive detail. The production of the different spore types of rust fungi is shown using three-dimensional computer animations. Additionally, this informative film shows the life cycles of leaf or brown rust of rye (<i>Puccinia recondita</i> f.sp. <i>recondita</i>), stem or black rust of wheat (<i>Puccinia graminis</i>), leaf or brown dwarf rust of barley (<i>Puccinia hordei</i>), and yellow or stripe rust of wheat (<i>Puccinia striiformis</i>).	
2.2 Fusarium Diseases of Wheat (12:30 min)	6–7
Fungi of the genus <i>Fusarium</i> are of great economic importance worldwide because they cause crop losses and produce mycotoxins, which can cause severe poisoning if consumed by humans and livestock. This movie depicts the life cycles of <i>Fusarium culmorum</i> and <i>F. graminearum</i> (teleomorph: <i>Gibberella zeae</i>) using three-dimensional computer animations blended with real images. Particularly, the modes of infection as well as epidemiological spread of the disease are exhaustively shown. Because diseases caused by <i>Fusarium</i> fungi are difficult to control using fungicides, this movie also shows agronomical means for successful disease management in wheat production.	
Glossary	8–14



Leaf Rust of Wheat

(*Puccinia recondita* f. sp. *tritici*, syn. *P. tritricina*)

(1–4) Leaf rust pustules – the uredinia – get their typical rusty color from the urediniospores that mature in them. Urediniospores are easily detached by the wind and carried to other wheat leaves. Here they remain until dew or rain wets the leaf, followed by a warm night. Under these optimal conditions, they germinate rapidly. The interior of the leaf is infected via stomata.

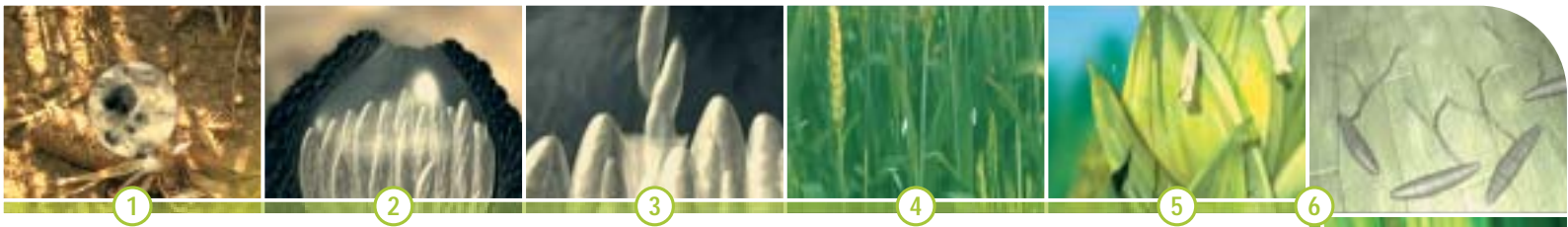
(5–6) In the cavity beneath the stoma, the tip of the penetration hypha dilates. From this vesicle new hyphae emerge, forming a mycelium that grows between the plant's cells. In warm weather, it takes just one week following infection for a new uredinium to break open on the leaf surface.

(7) The reproductive cycle of the urediniospores is repeated several times while the wheat is growing. This explains the exponential increase in the severity of infection, particularly when rust-prone varieties are grown during warm weather.

(8–10) Toward the end of the vegetative period, on rust-infected wheat leaves, a second spore type develops: with these teliospores the sexual stage in the life cycle of *Puccinia recondita* begins. The teliospores survive the winter on stubble residues, germinating the following spring. The germ tube bends, forming a basidium, a structure on which haploid basidiospores are produced that belong to either the + or - mating types.

(11–20) *P. recondita* requires an appropriate alternate host to complete its life cycle. Basidiospores of leaf rust of wheat infect *Thalictrum*. After some time a fungal organ called a pycnium develops. Pycnia are of different mating types (+ or -), depending on the mating type of the infecting basidiospore. Within the pycnia, haploid pycniospores are formed. Pycniospores of the + mating type are transferred to pycnia of the - type, and vice versa. Two nuclei of each mating type pair up, forming dikaryotic parent cells for the aeciospores. These are produced within a cuplike aecium. After being released, the aeciospores are carried by the wind back to the other host, the cereal.





Fusarium Diseases of Wheat

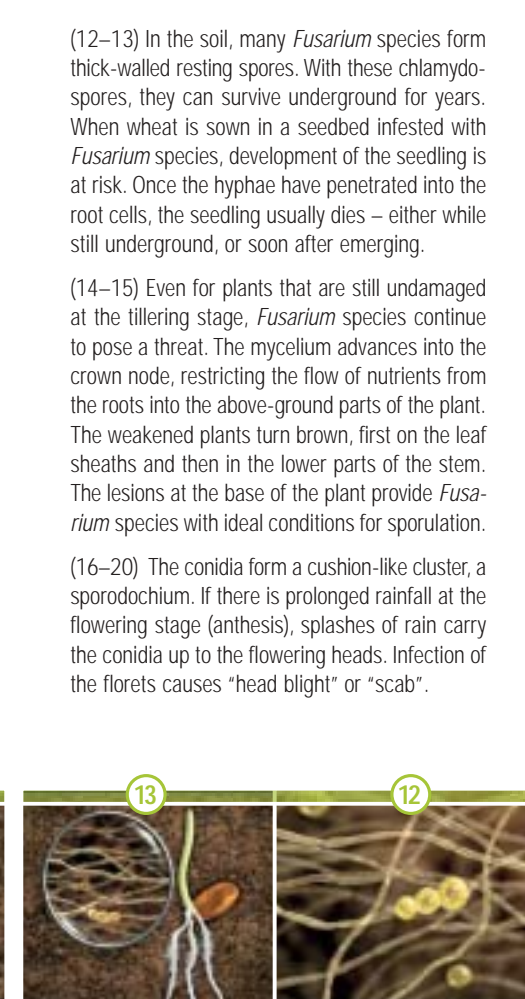
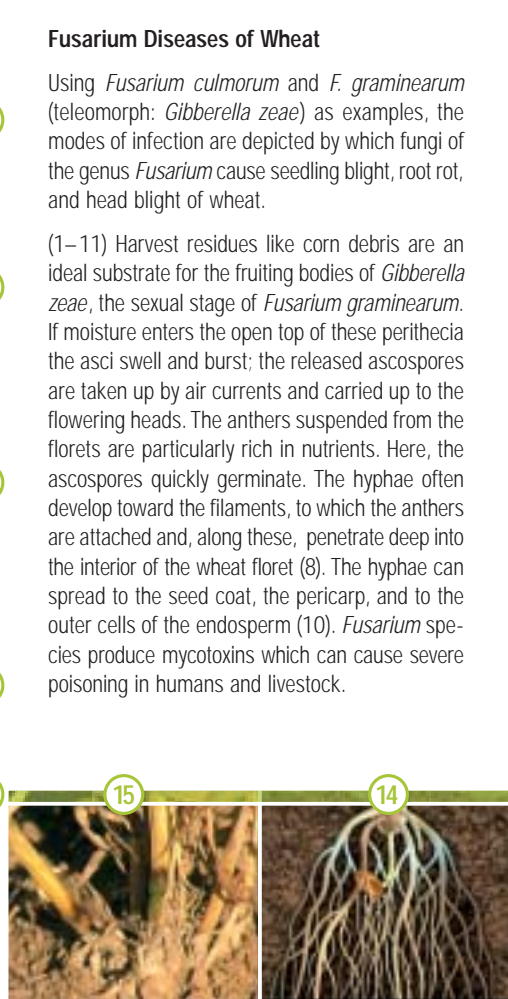
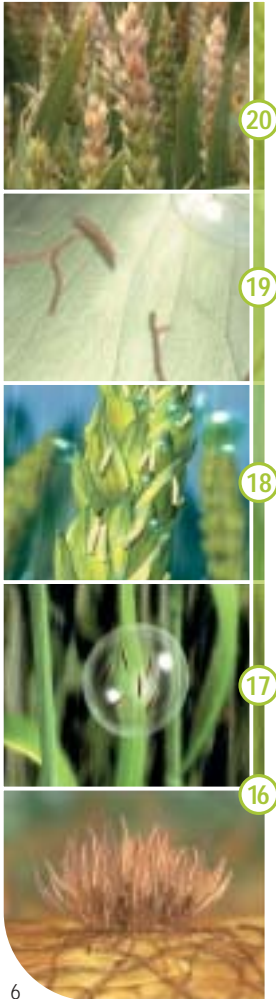
Using *Fusarium culmorum* and *F. graminearum* (teleomorph: *Gibberella zeae*) as examples, the modes of infection are depicted by which fungi of the genus *Fusarium* cause seedling blight, root rot, and head blight of wheat.

(1–11) Harvest residues like corn debris are an ideal substrate for the fruiting bodies of *Gibberella zeae*, the sexual stage of *Fusarium graminearum*. If moisture enters the open top of these perithecia the asci swell and burst; the released ascospores are taken up by air currents and carried up to the flowering heads. The anthers suspended from the florets are particularly rich in nutrients. Here, the ascospores quickly germinate. The hyphae often develop toward the filaments, to which the anthers are attached and, along these, penetrate deep into the interior of the wheat floret (8). The hyphae can spread to the seed coat, the pericarp, and to the outer cells of the endosperm (10). *Fusarium* species produce mycotoxins which can cause severe poisoning in humans and livestock.

(12–13) In the soil, many *Fusarium* species form thick-walled resting spores. With these chlamydo-spores, they can survive underground for years. When wheat is sown in a seedbed infested with *Fusarium* species, development of the seedling is at risk. Once the hyphae have penetrated into the root cells, the seedling usually dies – either while still underground, or soon after emerging.

(14–15) Even for plants that are still undamaged at the tillering stage, *Fusarium* species continue to pose a threat. The mycelium advances into the crown node, restricting the flow of nutrients from the roots into the above-ground parts of the plant. The weakened plants turn brown, first on the leaf sheaths and then in the lower parts of the stem. The lesions at the base of the plant provide *Fusarium* species with ideal conditions for sporulation.

(16–20) The conidia form a cushion-like cluster, a sporodochium. If there is prolonged rainfall at the flowering stage (anthesis), splashes of rain carry the conidia up to the flowering heads. Infection of the florets causes “head blight” or “scab”.



Glossary *

Aeciospore: dikaryotic spore of a rust fungus produced in an aecium; in heteroecious rusts, a spore stage that infects the alternate host.



Aecium

Aecium, pl. **aecia**: the cup-like fruiting body of a rust fungus in which the first dikaryotic spores (aeciospores) are produced.

Alternate host: one of two kinds of plant on which a heteroecious rust must develop in order to complete its life cycle.

Anamorph: the asexual stage in the life cycle of a fungus.

Anther: terminal saclike structure (microsporangium) of stamens (male part of flowers) bearing haploid pollen.

Appressorium, pl. **appressoria**: a swelling of a fungal germ tube stimulated by contact with surface of host; acts as an adhesion organ in which pressure develops for the physical penetration of the host.

Ascomycetes: a group of fungi that reproduces sexually by formation of ascospores borne in a saclike structure called an ascus.

Ascospore: sexual spore borne in an ascus.

Ascus, pl. **asci**: saclike structure of ascomycetes containing sexual ascospores (typically eight) and usually borne in a fungal fruiting body.

Asexual stage, syn. **anamorph**: vegetative stage of fungi; often forming conidial spores.

Assimilate: photosynthetic product of plants (mainly sugars, amino acids) produced in green plant parts and used to form plant biomass; basic source of nutrition for many parasitic fungi.

Autoecious: in reference to rust fungi, producing all spore forms on one species of host plant (see heteroecious).



Basidium

Basidiomycetes: a fungus group characterized by the formation of external basidiospores on basidia.

Basidiospore: haploid sexual spore produced on a basidium.

Basidium, pl. **basidia**: a structure on which haploid basidiospores are produced externally.

Biotroph, syn. **obligate parasite**: an organism that can live and multiply only on another living organism.

Blight: sudden, severe, and extensive spotting, discoloration, wilting, or destruction of leaves, flowers, stems, or entire plants.

* Many of the definitions listed are based on the *Illustrated Glossary of Plant Pathology*, APS Education Center (Authors: C. J. D'Arcy, D. M. Eastburn, and G. L. Schumann)

Chlamydospore: thick-walled asexual resting spore formed from hyphal cells (terminal or intercalary) that can function as an overwintering stage.

Chromosome: structure containing the genetic information—genes—of an organism; in eukaryotes chromosomes are localized in the cell's nucleus.

Coleoptile: the sheath enclosing the stem of a seedling.

Conidiophore: simple or branched hypha on which conidia are produced.

Conidium, pl. **conidia**: asexually formed non-motile fungal spore transported by wind or water; immediately capable of germination.

Cotyledon: seed leaf; primary embryonic leaf within the seed.

Crown: in cereals, junction of root and stem of a plant, usually at the soil line.

Dikaryotic: having two sexually compatible haploid nuclei per cell that divide simultaneously.

Diploid: having two complete sets of chromosomes (see haploid).

Dormancy: a condition of suspended growth and reduced metabolism of an organism, generally induced by internal factors or environmental conditions as a mechanism of survival.

Emergence: growth of the seedling shoot through the surface of the soil.

Endosperm: nutritive tissue formed within the embryo sac of seed plants.

Epidemic: phase of development of a disease characterized by a marked increase in the numbers of a pathogen and infections of the host; epidemic development of disease usually causes a corresponding decrease in yield.

Exponential (spread): the courses of epidemics often follow an exponential mathematical function.

Filament: threadlike structure, to which the pollen-bearing anther is attached.

Flowering (anthesis): developmental stage of plants when the sexual organs (pistil and stamens) are maturing and pollination takes place.

Forma specialis, abbr. **f. sp.** (pl. **formae speciales**): a taxonomic group within a pathogenic species defined in terms of host range; members of different *formae speciales* affect different groups of plants.



Crown



Filament

Form genus: a genus based on morphology and not on evolutionary relationships.

Fruiting body: any of various complex, spore-bearing fungal structures.

Fusarium: a form genus of fungi comprising anamorphic ascomycetes; among the teleomorphs are members of the genus *Gibberella*.

Fusarium culmorum: fungal pathogen that causes seedling blight, root rot, and head blight of small grains, and stalk, ear and root rot of corn; it produces a number of mycotoxins.

Fusarium graminearum (teleomorph: *Gibberella zeae*): fungal pathogen that causes seedling blight, root rot, and head blight of small grains, and stalk, ear and root rot of corn; it produces a number of mycotoxins.

Fusarium head blight (FHB): a disease of wheat and barley caused by *Fusarium graminearum* (teleomorph: *Gibberella zeae*), *Fusarium culmorum* and several closely related species of the genus *Fusarium*;

Fusarium head blight develops rapidly under favorable conditions, often leading to substantial losses in grain yield and quality. The pathogens may produce toxic substances (mycotoxins) in infected grain that pose health risks to animals and humans.

Germ tube, syn. germination hypha: germinating tube of hypha of fungal spore; usually secretes mucilaginous sub-



Germ tube stances which promote close contact with the plant surface.

Gibberella zeae: teleomorph of *Fusarium graminearum*.

Haploid: having a single complete set of chromosomes (see diploid).

Haustorium, pl. haustoria: organ of fungi formed inside host cells to absorb nutrients.

Head, syn. ear: inflorescence of cereals.

Heading: growth stage in cereals: head escaping through split of sheath in wheat or oats, awns just showing in barley.

Heteroecious: pertaining to a rust fungus requiring two unrelated host plants for completion of its life cycle (see autoecious).

Heterothallic: condition in which sexual reproduction can occur only via the interaction of genetically different mycelia (see homothallic).

Homothallic: condition in which sexual reproduction occurs with a single thallus; self-fertile (see heterothallic).

Honeydew: sugary ooze or exudate.

Host: living plant attacked by or harboring a parasite or pathogen.

Hypha, pl. hyphae: single, tubular filament of fungal thallus or mycelium; the basic structural unit of a fungus.

Infection: entering, invasion, or penetration of a host (plant) by a pathogen in order to establish a parasitic relationship.

Inoculum, pl. inocula: pathogen or its parts, capable of causing infection when transferred to a favorable location on a host.

Karyogamy: the fusion of nuclei.

Leaf rust (syn. brown rust) of barley: a disease of barley caused by the fungus *Puccinia hordei*.

Leaf rust (syn. brown rust) of rye: a disease of rye caused by the fungus *Puccinia recondita* f. sp. *recondita*.

Leaf rust (syn. brown rust) of wheat: a disease of wheat caused by the fungus *Puccinia recondita* f. sp. *tritici* (syn. *Puccinia triticina*).

Life cycle: cyclical succession of stages in the development of organisms.

Macroconidium, pl. macroconidia: the larger of two kinds of conidia formed by certain fungi (see microconidium).

Macrocyclic: describing a rust fungus that typically exhibits all five spore stages of the rust life cycle (see microcyclic).

Mating types: compatible strains, usually designated + and - or A and B, necessary for sexual reproduction in heterothallic fungi.

Meiosis: process of nuclear division in which the number of chromosomes per nucleus is halved, i.e. converting the diploid state to the haploid state (see mitosis).

Metabasidium, pl. metabasidia: a structure in which meiosis occurs in members of the basidiomycetes.

Microconidium, pl. microconidia: the smaller of two kinds of conidia formed by certain fungi (see macroconidium).

Microcyclic: describing a rust fungus that produces only teliospores and basidiospores (see macrocyclic).

Microdochium nivale (teleomorph: *Monographella nivalis*): fungal pathogen that causes snow mold and head blight of small grains, especially in cool to cold temperate climates; formerly described as *Fusarium nivale*; not known to produce mycotoxins.



Mating types

Mitosis: nuclear division in which the chromosome number remains the same (see meiosis).

Mycelium, pl. **mycelia**: accumulations of hyphae constituting the body (thallus) of a fungus.

Mycotoxin: poisonous compound produced by a fungus; the term is usually reserved for fungal metabolites that are toxic to man and/or animals.

Necrosis: death of cells or tissue, usually accompanied by black or brown darkening.

Nucleus, pl. **nuclei**: in eukaryotes, the cell structure – surrounded by a membrane – that contains chromosomes and controls heredity.

Parasite, adj. **parasitic**: organism that lives in intimate association with another organism on which it depends for its nutrition; not necessarily a pathogen.

Penetration: initial invasion of a host by a pathogen.

Penetration hypha, syn. **penetration peg**: a specialized, narrow, hyphal strand formed below the appressorium with which the fungus penetrates the cell wall via high pressure and the simultaneous activity of cell wall degrading enzymes.

Pericarp: seed coat, fruit wall.



Perithecium containing asci

Perithecium, pl. **perithecia**: flask-shaped, thin-walled fungal fruiting body containing asci and ascospores; spores are released through a pore (ostiole) at the apex.

Plasmogamy: the fusion of the cytoplasm of two or more cells; precedes karyogamy.

Pollen: male sex cells produced by anthers (pollen sacs) of flowering plants.

***Puccinia graminis* f. sp. *tritici*:** fungal pathogen that causes stem rust (syn. black rust) of wheat.

***Puccinia hordei*:** fungal pathogen that causes leaf rust (syn. brown rust) of barley.

***Puccinia recondita* f. sp. *recondita*:** fungal pathogen that causes leaf rust (syn. brown rust) of rye.

Puccinia recondita* f. sp. *tritici (syn. ***Puccinia triticina***): fungal pathogen that causes leaf rust (syn. brown rust) of wheat.

***Puccinia striiformis*:** fungal pathogen that causes stripe rust (syn. yellow rust) of wheat, barley, and rye.

Pustule: small blisterlike elevation of surface of leaves or other plant parts formed as spores emerge.

Pycniospore, syn. **spermatium**: haploid, sexually derived spore formed in a pycnium of rust fungi.

Pycnium, pl. **pycnia** (syn. **spermagonium**): globose or flask-shaped haploid fruiting body of rust fungi bearing receptive hyphae and pycniospores.

Rachis: elongated main axis of an inflorescence.

Receptive hypha: the part of a rust fungus pycnium (spermagonium) that receives the nucleus of a pycniospore (spermatium).

Rust: a disease caused by a specialized group of basidiomycetes that often produces spores of a rusty color.

Saprophyte: organism that obtains nourishment from non-living organic matter.

Scab: roughened, crustlike diseased area on the surface of a plant organ.

Sexually compatible: cross-fertile or able to be cross-mated.

Sexual reproduction: reproduction involving fusion of two haploid nuclei (karyogamy) to form a diploid nucleus that is followed by meiosis (reduction division) back to haploid nuclei at some point in the life cycle; results in genetic recombination.

Smut: a group of fungi in the basidiomycetes that typically releases masses of black dusty teliospores at maturity.

Snow mold: a (seedling) disease of small grains caused by the fungus *Microdochium nivale*.

Sorus, pl. **sori**: compact fruiting structure, especially spore masses in rust and smut fungi.

Spikelet: spike-like appendage comprised of one or more reduced flowers and associated bracts; unit of inflorescence in grasses.

Spore: mono- or multicellular reproductive organ of fungi; it serves for reproduction or proliferation of the species or as a dormant stage (thick-walled resting spores) for surviving unfavorable environmental conditions.

Sporodochium, pl. **sporodochia**: superficial, cushion-shaped asexual fruiting body consisting of a cluster of conidiophores.



Pycnium



Sporodochium

Sporulation: the process of producing spores.

Stem rust (syn. black rust) of wheat: a disease of wheat caused by the fungus *Puccinia graminis* f. sp. *tritici*.

Sterigma, pl. **sterigmata:** small diverticula (usually 4) that form on the apex of each basidium, and which support the basidiospores (basidiomycetes); in other fungi sterigmata may bear also conidia or sporangia.

Stigma: (female) portion of a flower that receives pollen and on which the pollen germinates.



Stigma and style

Stoma, pl. **stomata:** slitlike opening in the epidermal cell layer of a plant for gas exchange, e.g. carbon dioxide, oxygen; composed of two guard cells; penetration route for fungal pathogens like rusts.

Stripe rust (syn. yellow rust): a disease of wheat, barley, and rye caused by the fungus *Puccinia striiformis*.

Style: portion of a flower located between the stigma and the ovary.

Teleomorph: the sexual stage in the life cycle of a fungus.

Teliospore: thick-walled resting spore produced by some fungi, notably rust and smut fungi, from which the basidium is produced.

Telium: fruiting body (sorus) of a rust fungus that produces teliospores.

Thallus: the entirety of a fungus (hyphae, mycelium, fruiting bodies, spores).

Tiller: a lateral shoot from a crown bud; common in grasses.

Tillering: growth stage in cereals: forming of tillers.

Urediniospore: the asexual, dikaryotic, often rusty-colored spore of a rust fungus, produced in a fruiting body called an uredinium; the "repeating stage" of a heteroecious rust fungus, i.e. capable of infecting the host plant on which it is produced.

Uredinium, pl. **uredinia:** fruiting body (sorus) of rust fungi that produces urediniospores.

Vegetative period: period of growth (sowing to harvest); in the case of winter crops, e.g. winter wheat, from fall to summer of the following year.

Volunteer: self-set plant; plant seeded by chance.