Food Microbiology

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Important Bacteria in Foods

Acinetobacter

1) *Neisseriaceae*
2) Gram(-)
3) rods short and plump approaching cocci – pairs and chains – also large irregular cells and filaments noted in all cultures.
4) oxidative metabolism, oxidase(-),catalase(+), no flagella but twitching motion on solid media, strict aerobes, resistant to penicillin
5) 30 to 32℃ optimum
6) optimum pH 7.0
7) soil and water
8) usually not identified
9) psychrotrophic
10) spoil meat, poultry, fish, eggs and dairy products; also suggested for single cell protein to utilize ethanol and gas oil
11) same as *Pseudomonas*

Aeromonas

1) *Vibrionaceae*
2) gram (-)
3) rods with rounded ends to cocci occurring singly, in pairs or chains
4) facultative anaerobes that can either be fermentative or oxidative; motile by polar flagella or non-motile; oxidase (+); catalase (+); casein; starch and gelatin hydrolyzed
5) 0 to 41℃ range with 20 to 30℃ optimum
6) range pH 5.5 to 9.0
7) water
8) *A. hydrophila*
9) frequently mistaken for members of Enterobacteriaceae but oxidase (+) and nitrate reduction are characteristic of *Aeromonas* speies; can grow in psychrotrophic range
10) cause enteric infection from contaminated fish; spoil fresh meat, poultry, and fish; cause black rot in eggs
11) Isolate on enteric media and follow by biochemical and serological tests

Alcaligenes

1) Genera of uncertain affiliation
2) Gram(-)
3) single rods to cocci
4) respiratory metabolism, never fermentative, oxidase (+), obligate aerobe, motile with peritrichous flagella, nonpigmented, alkaline reactions
5) optimum 20 to 37℃
6) optimum pH 7.0
7) intestinal tract, water and marine environments, dairy products
8) most species that appear in the literature are no longer recognized as distinct species except for *A. faecalis*
9) alkaline reaction, especially in litmus milk
10) spoil meat, poultry, eggs, fish; produce ropy milk and slimy cottage cheese
11 same as *Pseudomonas*

Alteromonas

1) Genera of uncertain Affiliation
2) gram(-)
3) straight or curved rods
4) respiratory metabolism, motile by single polar flagellum, require seawater for growth
5) optimum of 20-30℃, some grow at 4℃ and none at 45℃
6) optimum near neutral
7) marine environments
8) usually not given
9) need seawater
10) spoilage of fish, produce sulfur-containing compounds (mercaptans, H2S, dimethyl sulfide)
11) seawater needed in media (see Bergey's Manual of Systemic Bacteriology Volume 1, 1984)

Acetobacter

1) *Acetobactereaceae*
2) Gram(-)
3) straight or curve ellipsoidal to rod shaped; single, pairs or chains
4) respiratory and never fermentative, strict aerobes, motile by peritrichous flagella or nonmotile, oxidize ethanol to acetic acid, catalase (+), oxidase (-)
5) 5 to 42℃ with 25-30℃ optimum
6) 4 to 7.0 with 5.4 to 6.3 optimum
7) on fruits and vegetables
8) *A. aceti* – vinegar production
9) oxidize acetate and lactate to carbon dioxide plus water
10) vinegar production, cause ropy and sour beer due to acetification, rot in apples and pears
11) medium with 0.5% yeast extract, 1.5% ethanol, and 2.5% agar

Arthrobacter

1) Coryneform group
2) Gram(+) to Gram (-) variable – granules retain stain if cell loses it
3) pleomorphic (cells change form during life cycle) – irregular rods change to coccoid cells
4) catalase (+), strict aerobes, respiratory metabolism & never fermentative, cellulose not attacked
5) 0 to 37°C, optimum 20 to 30°C
6) optimum neutral to alkaline
7) soil
8) species usually not identified
9) psychrotrophic, pectinolytic, some thermoduric
10) spoil meat and poultry
11) same as *Corynebacterium*

Bacillus

1) *Bacillaceae*
2) Gram(+), can also stain gram variable
3) rods – single or chains with endospores
4) catalase (+), usually motile, strict aerobes or facultative anaerobes, some are proteolytic and/or lipolytic, few form gas
5) -5 to 75°C (depends on species)
6) 2 to 9.3
7) Soil, water, air, dust

8.) ***B. subtilis*** – strict aerobe, pH 5.5 to 8.5, temp. 5 to 55℃ with 30℃ optimum, reduces nitrate to nitrite, cause ropy bread, rancid salad dressing & used to manufacture amylases & proteases

B. licheniformis – ferments glucose anaerobically, temp. 15 to 55℃ with optimum 30-50℃, grows in salt of 7.5 to 15%, reduces nitrate to nitrite, red pigment if iron present, cause ropy bread and gas in canned meat under anaerobic conditions in presence of sugar and nitrate

B. cereus **– temp. 10 to 45℃with optimum of 30℃, pH 4.9 to 9.3, aerobic or facultative anaerobic, gas under anaerobic conditions if nitrate present, proteolytic (sweet curdles milk-clot & no acid), found in spices, food poisoning (spores survive 100℃ for 3 minutes)**

B. megaterium – temp. 3 to 45℃, aerobic, usually pigmented (yellow, pink, brown), usually motile, spoils salad dressing, sours fresh meat & hams

B. polymyxa – temp. 5 to 45℃, facultative anaerobe (acid & gas anaerobically), bulging spores, needs biotin, grows on proteose peptone agar, minimum pH 3.8 to 4.0, gassiness in cheese, spoilage of acid foods due to under-processing or entrance due to defective seals

B. macerans – temp. 5 to 50℃, facultative anaerobe, bulging spores, needs biotin and thiamine, dose not grow on proteose-peptone agar, minimum pH 3.8 to 4.0, spoilage of acid foods due to under-processing or entrance due to defective seals

B. stearothermophilus **– obligate thermophile temp. 30-75℃, growth at 65℃ = stable characteristic, spores need 121℃ for 20 minutes to destroy, dose not grow at pH 5.0, sensitive to azide & some acid, thermostable enzymes ribosomes (70℃ for 24h), "thermophilic flat sour " in canned foods that are low acid**

B. coagulans **– temp. 15 to 60℃, pH 4.0 to 6.0 optimum, spores (121℃ for 0.7 minutes to destroy),"flat sour" in canned foods, used to produce lactic acid commercially**

Alicyclobacillus

- The first Alicyclobacillus spp. was isolated in 1982
- A. acidoterrestris, was identified in 1984 as the causative agent in spoilage of commercially pasteurized apple juice and other fruit juices.
- 20 species and 2 subspecies have been identified
- thermo-acidophilic, non-pathogenic, spore-forming bacteria that can survive the typical heat processing of fruit juices and concentrates
- Guaiacol (2-methoxyphenol) and halophenols (2,6-bromophenol, 2,6-chlorophenol) were identified as the offensive smelling agent in many Alicyclobacillus spp. related spoilage.

Heat resistance

Concentrated juice	Soluble solids (°Bx)	pH	Temperature (°C)	D-value [±SD]a (min)
Blackcurrant (Light)	26.10	2.50	91	3.84 [±0.49]
Blackcurrant	58.50	2.50	91	24.10 [±2.70]
Grape (Concord)	30.00	3.50	85	76.00
Grape (Concord)			90	18.00
●			95	2.30
Grape (Concord)	65.00	3.50	85	276.00
●			90	127.00
			95	12.00
Mango	NR	4.00	80	4.00 [±1.50]
			85	25.00 [±0.10]
			90	11.66 [±1.80]
			95	8.33 [±2.00]
Lemon (Clarified)	50.00	2.28	82	17.36
			86	18.06
			92	7.60
			95	6.20
	50.00	2.80	82	25.81
			86	22.01
			92	15.35
			95	11.32

Bifidobacterium

1) *Actinomycetaceae*
2) Gram(+)
3) variable rod shapes that may be branched; club, Y or V forms
4) saccharoclastic, glucose fermented to L (+) lactic and acetic in 2:3 ratio, catalase(-), benzidine (-), anaerobic but slightly oxygen tolerant if CO2 present
5) optimum 36 to 38 and none at 20 or 46.5℃
6) optimum 6 to 7 with little growth below pH 5.5
7) alimentary and instestinal tracts of humans and animals
8) *B. bifidum* suggested for colonizing intestinal tract of infants
9) anaerobic
10) possible fecal indicators
11) anaerobic conditions in presence of CO2

Brevibacterium

1) Coryneform Group (uncertain affliation)
2) Gram(+)
3) short, non-branching, non-sporeforming rods that resemble *Corynebacterium* spp.
4) *B. linens* may be synonymous with *Arthrobacter globiformis*, orange-red pigment
5) optimum of 20 to 30℃
6) optimum around 7
7) soil, water, dairy products
8) all species are uncertain
9) may be reclassified as *Corynebacterium* or *Arthrobacter* species
10) surface of soft ripened cheese (Limburger & Brick)
11) same as *Corynebacterium*

Campylobacter

1) *Spirillaceae*
2) Gram(-)
3) slender spirally curved rods, old cells forms coccoid bodies
4) respiratory metabolism, microaerophilic to anaerobic, motile with single polar flagellum at one or both ends, oxidase (+), energy form amino acids or TCA cycle intermediates and not carbohydrates
5) growth at 25°C, but usually not 42°C, optimum = 37°C
6) optimum = pH 7.0
7) infected animals, intestinal tract, water
8) *Campylobacter fetus* subsp. *jejuni*

   Campylobacter fetus subst. *intestinalis*
9) motile by corkscrew action, growth best in 5% O_2 and 10% CO_2
10) food gastroenteritis from water, raw milk, undercooked pork and poultry
11) complex, see current literature

Citrobacter

1) *Enterobacteriaceae*
2) Gram(-)
3) rods
4) uses citrate as sole carbon source, motile with peritrichous flagella, grows on KCN, carbohydrate fermented to acid & gas (CO_2 + H_2), IMVC (±+-+)
5) optimum 30 to 37°C
6) optimum around neutral pH
7) water, feces, urine, intestinal tract
8) usually not identified
9) can be psychrotrophic, common in fecal matter
10) spoils fresh meat & poultry
11) same as for *Escherichia*

Clostridium

1) *Bacilaceae*
2) Gram(+) (especially in early stages)
3) rods – with oval spore that distends the bacilli
4) catalase(-), nonmotile or motile with peritrichous flagella, anaerobic, saccharolytic or proteolytic, produce acid and gas
5) 0 to 70°C, optimum depends on species
6) 3.0 to 8.5
7) Soil, water, intestinal tract
8) ***C. butyricum*** – temp. optimum 25 to 37°C, requires biotin, gaseous spoilage of acid foods, butyric fermentation in fruits and vegetables, stormy fermentation in milk and hams

C. pasteurianum – optimum. 37°C, spores not heat resistant, gassiness in cheese and acid foods

C. sporogenes – optimum temp. 30 to 40°C, digests milk, putrefactive anaerobe that spoils acid and low acid foods, 【PA 3679】is a tested organism for heat processing canned foods, causes explosion in chocolates

C. botulinum – optimum temp. 30 to 40°C, putrefactive, produces potent neurotoxin, food intoxication mainly form home processed foods and usually is type A. Type E from fish, spores 120°C for 4 minutes to destroy, toxin Type A 80°C for 6 minutes to destroy

C. perfringens – optimum temp. 45°C, nonmotile, require amino acids and growth factors, pH 5 to 8, H_2S produced in most media, spores need minutes to 6h at 100°C for inactivation, produced toxin (α-in US) in intestine from cooked meat and related foods causes food poisoning

C. thermosaccharolyticum – obligate thermophile with optimum at 55°C, thermophilic anaerobe (TA) causing hard swell in non-acid canned foods, coagulates milk, degrades sugar

C. putrefaciens – optimum temp. 20 to 25°C with 0 to 30°C range, nonmotile, produce H_2S and gas, putrefactive, spores 100°C for 10 minutes to destroy, spoil ham and other meats

Corynbacterium

1) Coryneform Group
2) Gram(+) – can lose stain easily and only granules remained
3) straight and curved rods frequently showing club-shaped swelling, produce palisade layers
4) catalase (+), facultative anaerobic or aerobic, non-motile or motile
5) 0 to 40℃
6) 5 to 7.5
7) soil, water, air, plants, intestinal tract
8) *C. bovis* – mastitis in cows

   C. diptheriae – diphtheria – may be transported by food
9) Most mesophiles, some psychrotrophs
10) *Corynebacterium s*pecies – various plant disease (rots & wilting); spoilage of meat, poultry and seafoods
11) use media such as trypticase soy agar, plate count agar, etc,; characterize by biochemical tests and morphology

Desulfotomaculum

1) *Bacillaceae*
2) Gram(+)
3) straight or curved rods with rounded ends, single or sometimes in chains; spores are oval to round, terminal to subterminal, and cause swelling of cells
4) anaerobic, catalase (-), sulfate reduced to sulfide, respiratory metabolism, motile by peritrichous flagella
5) 30 to 70°C with optimum of 35 to 55°C
6) sensitive to acid, grows at pH 6.0 or above
7) soil, fresh water, waste water, rumen
8) *D. nigrificans* – thermophilic temp. 45-70°C with optimum of 55°C
9) Reduces sulfate, sulfites, and other sulfur compounds to H_2S; thermophilic sporeformer
10) causes sulfate spoilage of canned foods (peas, corn)
11) use anaerobic conditions and thermophilic temperatures

Enterobacter

1) *Enterobacteriaceae*
2) Gram(-)
3) short rods
4) catalase (+), oxidase (-), no H_2S, IMVC (--++), acid & gas by 2,3 butanediol fermentation, motile by peritrichous flagella, citrate & acetate used as sole carbon
5) optimum 30 to 37°C
6) 4.5 to 8.5
7) plants, soil, water & sometimes intestinal tract
8) *E. aerogenes* – ropy milk, gas in cheese
   E. cloacae – early sauerkraut manufacture
9) coliform group of plant origin, predominant in absence of oxygen in refrigerated foods (vacuum packed meats)
10) see 8 and 9 above, also spoil meat, fish and milk
11) same as *Escherichia*

Erwinia

1) *Enterobacteriaceae*
2) Gram(-)
3) single straight rods
4) catalase (+), oxidase (-), acid but gas weak or absent, facultative anaerobes, motile by peritrichous flagella, degrade pectins, rarely produce urease or lipases, pigment yellow to red
5) optimum 27-30℃, range 1to 40℃
6) 4 to 8.8, optimum 6.0 to 7.0
7) plants
8) *E. carotovora*
9) plant pathogens
10)cause soft rot, wilt, and necrosis in fruits and vegetables
11)isolate on standard plate count agar and do biochemicals

Escherichia

1) *Enterobacteriaceae*
2) Gram(-)
3) single or paired rods
4) facultative anaerobes, catalase (+), oxidase(-), motile by peritrichous flagella or nonmotile, uses acetate but not citrate as sole carbon source, lactose fermented by most; glucose fermented to lactic, acetic and formic acids plus gas (H_2+CO_2); KCN not used, H_2S not produced on TST, IMVC reaction (++－－)
5) 0-46℃ optimum 30 to 37℃
6) 4.5 to 8.5
7) intestinal tract

8) *E. coli*

Enteropathogenic *E. coli* (EEC), **Enterotoxigenic** *E. coli* (ETEC), *E. coli* O157:H7

9) used as fecal indicator for water foods

10) spoils meat, poultry, fish, eggs, dairy products; EEC causes diarrhea food poisoning especially in infants and travelers; ETEC causes traveler's diarrhea; *E. coli* O157:H7 causes hemorrhagic colitis

11) use EMB of Violet Red Bile agars and confirm with biochemical tests and serology

Flavobacterium

1) Genera of uncertain affiliation
2) Gram (+)
3) coccibacilli to slender rods
4) respiratory metabolism, motile by pertitrichous flagella or nonmotile, pigmented (yellow, red, orange, brown), some facultative anaerobes
5) grow best below 30°C
6) 5 to 9, optimum 7.0
7) soil, water, vegetation, dairy products
8) usually not identified
9) many psychrotrophic
10) spoil fish, poultry, eggs, meat, dairy products
11) same as *Pseudomonas*

Gluconobacter

1) *Acetobacteraceae*
2) Gram (-) to Gram variable
3) elliposoidal to rod-shaped, occur in pairs, chains or singly
4) respiratory metabolism, never fermentative, catalase (+), strict aerobes, motile with 3 to 8 polar flagella or nonmotile, oxidizes ethanol to acetic acid
5) optimum 25 to 30°C, no growth at 37°C
6) 3.6 to 7 with 5.5 to 6.0 optimum
7) flowers, fruits and vegetables
8) *G. oxydans*
9) will not oxidize lactate to CO_2
10) causes ropiness and souring of beer by acetification; occur in baker's yeast, honey, fruits soft drinks; cause rot in apples and pears
11) medium: yeast extract (0.5%), glucose (5%), actidione (0.01%), and bromophenol blue (0.006%)

Klebsiella

1) *Enterobacteriaceae*
2) Gram (-)
3) capsulated rods – single, pairs or chains
4) oxidase (-), catalase (+), acid &gas by 2,3 – butanediol fermentation, H_2S not produced, nonmotile, IMVC (D,D,D,D), resistant to penicillin
5) optimum 35 to 37°C
6) optimum 7.2
7) respiratory and intestinal tracts
8) *K. pneumoniae* – causes pneumonia
9) one of coliforms – can be used as fecal indicator
10) food-borne spread of pneumonia not usually noted
11) isolate on enteric medium, such as MacConkey's; then do biochemical and serological tests

Lactobacillus

1) *Lactobacillaceae*
2) Gram (+)
3) rods – single or chains
4) catalase (-), Homo- or heterofermentative, nonmotile, nonsporeforming facultative anaerobes, rarely pathogenic, D,L or DL-Lactic Acid, complex nutritional requirements
5) 5 to 53°C; optimum 30 to 40°C
6) 3 to 9.6 optimum 5.5 to 5.8
7) plants, dairy products & intestinal tract

8) ***L. brevis*** – pickles, olives, bloaters in pickles, sausage

L. bulgaricus – Swiss cheese, buttermilk, yogurt, thermophile

L. casei – ropy milk, bread starter

L. lactis – thermoduric

L. plantarum – pickles, olives

L. helveticus – Emmental & Gruyere cheese

L. delbrueckii – soy sauce fermentation, beer & distilled spirits – sour mash

**L. fermentum* – gas in cheese (false eyes in Swiss)

L. leichmannii – Kumiss (fermented milk of Russia)

**L. viridescens* – greening of meat

**L. hilgardii* – deterioration of wine

**L. tricodes* – deterioration of wine

L. acidophilus – acidophilus milk

**L. buchneri* – deterioration of wine, sausage fermentation

Leuconostoc

1) *Streptococcaeae*
2) Gram (+)
3) cocci in pairs & chains
4) catalase (-), heterofermentative, nonmotile, complex growth and amino acid requirements, facultative anaerobes, L- lactic Acid
5) 10 to 40°C but some species vary
6) 3 to 9.6
7) plant surfaces, milk
8) ***L. cremoris*** – diacetyl (buttermilk, etc.)
   L. mesenteroides – pickles, olives & sauerkraut, slimy syrups & sugars
   L. oenos – spoil wines
   L. lactics – milk & dairy products, thermoduric
   L. dextranicum – spoils orange juice
9) must have fermentable carbohydrate, relatively inactive in litmus milk (no reduction or clot)
10) mainly fermented foods – see #8 above
11) same as for *Streptococcus*

Listeria

1) Genera of Uncertain Affiliation
2) Gram (+); may strain Gram (-) if cells are old
3) coccoid rods in chains of 3 to 5 cells or in filamentous forms; diptheroid palisade layers can be seen when stained
4) aerobic to microaerophilic (reduced O_2 and 5 to 10% CO_2), motile by peritrichous flagella (20 to 25℃), catalase (+), growth slow in absence of carbohydrate, ferments sugars (glucose, trehalose, salicin) to acid, hydrolyze esculin and polysorbate 80, produces small zone of β-hemolysis on blood agar, H_2S(-), O- and H-antigens used to differentiate serotypes, grows in 10% salt
5) range of 2.5 to 38℃; optimum 35 to 37℃
6) pH range 5.5 to 9.6
7) feces of animals and humans, vegetation, silage, soil

8) ***L. moncytogenes***

9) able to grow at refrigeration temperatures, produces gastroenteritis and leukocytosis and moncytosis (mild influenza-like illness to meningitis, bacteremia endocarditis, and central nervous system infection; many patients have other medical disorders or are on immunosuppressive drugs) with a mortality rate of around 50%

10)microorganism transported through milk or infected meat (rare)

11)isolate on sheep's blood agar, McBride's Listeria agar using atmospheres of 10% CO2, 5% O2 and 85% N2 and 35℃

Micrococcus

1) *Micrococcaceae*
2) Gram (+)
3) cocci-irregular clusters, single or pairs
4) catalase (+), tolerates 5-15% salt, water soluble pigment (yellow, orange & red), lysostaphin (-), nonmotile, strict aerobe
5) optimum = 25-30°C, range = 0 to 45°C
6) range = 5 to 8.5
7) fresh & salt water, air, soil, sewage plant surfaces, skin of humans & warm-blooded animals (essentially on all raw foods)
8) *M. luteus* --yellow

   M. roseus -- pink

   M. varians-- thermoduric

   M. radiodurans/irradiation-- resistant to

9) selective advantage:

(a) high salt foods

(b) use nitrate ion in place of oxygen – cured meats

(c) survive heating – milk pasteurization,

(d) more resistant to dehydration & radiation

(e) sensitive to acid – inhibited at pH 5

(f) grow at refrigeration temperatures

(g) produce lipolytic & proteolytic enzymes, reduce nitrate to nitrite, and oxidize organic substrates

(h) discolor food (yellow, pink) Note: Rarely primary source of spoilage since unable to grow rapidly & compete with other microorganisms – can be problems in above 8 cases if conditions are optimum.

10) (a) Brick & Surface ripened cheese-oxidize lactic acid & increase pH,
(b) Cheddar Chinese – flavor,
(c) Salt cured meat products – reduce nitrate which affects color fixation and also spoils bacon, ham & bologna,
(d) dry fermented sausage – controlled European fermentations

11) (a) medium with added salt,
(b) medium for lipolytic and proteolytic microorganisms,
(c) thermodurtic – 30 minutes at 62.8°C and then plate milk,
(d) medium designed for specific food product in mind.

Moraxella

1) *Neisseriaceae*
2) Gram(-)
3) short plump rods often approaching cocci; in pairs or chains
4) oxidative metabolism, strict aerobes, oxidase (+), catalase (+), sensitive to penicillin, no flagella but may have twitching motility on solid surfaces, carbohydrates not utilized
5) 32 to 35°Coptimum
6) 7 to 7.5 optimum
7) soil and water
8) usually not identified
9) parasitic on mucous membranes
10) spoilage of meat, poultry and fish – usually initiate spoilage with *Acinetobacter* and then *Pseudomonas* predominate
11) same as *Pseudomonas*

Pediococcus

1) *Streptococcaceae*
2) Gram (+)
3) cocci in pairs & tetrads
4) catalase (-), homofermentative, nonmotile, DL-Lactic Acid, facultative anaerobes, complex nutritional requirements
5) 7 to 45°C with optimum 25 to 32°C
6) 4 to 9.6
7) plant materials
8) *P. cerevisiae*
9) must have fermentable carbohydrate, grow in salt to 5.5%
10) fermentation of pickles; sauerkraut; summer sausage; cause ropiness, turbidity & sourness in beer
11) same as *Streptococcus*

Propionibacterium

1) *Propionobacteriaceae*
2) Gram(+)
3) nonsporeforming, pleomorphic, diptheroid (club-shaped) rods
4) anaerobic to aerotolerant, fermentative yielding propionic and acetic acids and carbon dioxide, catalase (+)
5) optimum 30 to 37°C
6) optimum pH 7.0
7) dairy products and intestinal tract
8) *P. freundenreichii* subsp. *shermanii*
9) Production of propionic acid
10) forms characteristic eyes in Swiss cheese, also contributes to flavor
11) isolate on yeast extract lactate medium and incubate anaerobically with 5% CO_2 for 7 to 10 days at 30°C

Proteus

1) *Enterobacteriaceae*
2) Gram(-)
3) rods in chains or pairs that can give coccoid or filamentous forms under special conditions
4) catalase(+), oxidase(-), motile by peritrichous flagella, nonpigmented, acid & sometimes gas from glucose, IMVC(+ + + D), urease(+), grows in KCN
5) 10 to 43℃
6) optimum 6 to 7
7) soil, water, intestine
8) usually not identified
9) produces swarming on solid media
10) spoil meat, eggs, seafood & dairy products; also proteolytic (putrefactive)
11) same as *Klebsiella*

Pseudomonas

1) *Pseudomonadaceae*
2) Gram(-)
3) single straight or curved rods
4) respiratory metabolism, never fermentative, strict aerobes, catalase(+), oxidase(+), motile by one or more polar flagella, some produce diffusible and/or fluorescent pigments(red, blue, green, yellow)
5) 4 to 43°C
6) most do not grow below pH 5.3-6.0
7) soil, water, intestinal tract, and on plants

8) ***P. fluorescens*** – fluorescent pigment

P .aeruginosa – of clinical importance

considerable regrouping of the gram negative rods has changed many of the names that appear in literature

9) (a) psychrotrophic growth is important; (b)use variety of noncarbohydrate compounds for energy; (c)lipolytic and/or proteolytic; (d)ability to synthesize own growth factors; (e)aerobic – grow fast & cause surface spoilage; (f)pigment formation discolors surface; (g)most important low temperature spoilage microorganisms

10)spoilage of meats, poultry seafood, eggs, dairy products

11)use trypticase soy agar or plate count agar and do biochemical tests (oxidase, catalase, penicillin sensitivity, flagella stain, etc.)

Salmonella

1) *Enterobacteriaceae*
2) Gram (-)
3) rod
4) acid & gas from glucose but not lactose, motile by peritrichous flagella,uses citrate as sole carbon sauce, oxidase (-), produces H_2S, IMVC (- + - +), mixed acid fermentation (lactic, formic acetic & succinic), catalase (+)
5) 7 to 47℃ with optimum at 37℃
6) 4-9 with optimum at 6.5 to 7.5
7) intestinal tract

8) ***S. typhi*** – typhoid fever

S. typhimurium – most often in food poisoning outbreaks

9) causes food infection due to ingestion of large number of cells, classified by serology (O, K, and H antigens)

10) all species can cause food poisoning; spoils meat, poultry & eggs in mesophilic range

11) use pre-enriched lactose broth for 24h 35℃ followed by selective enrichment in selenite-cystine and tetrathionate broths; streak on selective agars (Hektoen enteric, xylose lysine desoxycholate, bismuth-sulfite); characterize by biochemistry (TSI, LIA urease, etc.) and serology (O, H, K antisera)

Serratia

1) *Enterobacteriaceae*
2) Gram (-)
3) rods-some encapsulated
4) catalase (+), oxidase (-), many strains produce pink to red pigments, IMVC (- + D +), glucose may or may not be fermented with gas production, lactose not fermented
5) optimum 25 to 30°C
6) optimum around 7
7) soil and water
8) *S. marcescans*
9) some psychrotrophic and cause surface discoloration of meat and fish
10) spoil meat, poultry, eggs, seafood; also cause lipolytic degradation
11) same as *Klebsiella*

Shigella

1) *Enterobacteriaceae*
2) Gram (-)
3) short rods
4) acid but not gas from carbohydrates, oxidase (-), catalase (±), nonmotile, inhibited by KCN, H_2S not produced, IMVC (D + - -), aerobic
5) optimum 37℃
6) optimum 6.4 to 7.8
7) intestinal tract and polluted water
8) ***S. dysenteriae*** – bacillary dysentery
9) all species produce dysentery and are undesirable in foods: refrigeration usually prevents growth

10)cause dysentery when transmitted by water and food

11)use gram-negative broth followed by selective agars (low=MacConkey or Tergitol 7 Agar; intermediate=Xylose-Lactose-Desoxycholate (XLD); high=Salmonella-Shigella Agar or Hektoen Enteric Agar); confirm by biochemical tests and serology

Streptococcus

1) *Streptococcaceae*
2) Gram (+)
3) cocci in chains & pairs
4) catalase (-), homofermentative, non-pigmented, D-Lactic acid, facultative anaerobes, usually nonmotile, complex nutritional requirements
5) optimum 37℃; minimum & maximum vary with species
6) varies with species but generally 4 to 9.6
7) foods, beverages, animal body (nasopharynx, intestinal tract, etc.)

8)

	Pyogenic	Viridans	Enterococcus	Lactococcus
10℃	-	-	+	+
45℃	-	+	+	-
pH 9.6	-	-	+	-
6.5 % NaCl	-	-	+	-
	S. agalactiae	*S. thermophilus*	*S. faecium*	*S. lactis*
	S. pyogenes		*S. faecalis*	*S. cremoris*

9) must have fermentable carbohydrate, colonies remain small & not pigmented, catalase (-) because no cytochromes, high tolerance to acid

10) ***S. agalactiae*** – Mastitis in cows

S. pyogenes – Strep throat, scarlet fever

S. thermophilus – Swiss & Italian cheeses, yogurt & thermophilic

S. faecalis-indictors of fecal contamination, thermoduric, grows 5 to 50℃, proteolytic, produces acid in pickles and sauerkraut

S. faecium – common in plants, thermoduric

S. cremoris & ***S. lactis*** – starter bacteria (cottage cheese, Cheddar cheese, sour cream, etc.), slimy & ropy milk (long chain formation)

S. lactis – sour raw milk at 10-37℃

11) use selective media for lactics or acid-producers (Lactic Agar, Trypticase Soy Agar with Bromcresol purple, etc.)

Biochemical tests: gram reaction; catalase test; fermentation of sugars; tolerance to pH, temperature and salt

Staphylococcus

1) *Micrococcaceae*
2) Gram(+)
3) cocci – pairs or grapelike clusters (solid media)
4) catalase (+); facultative anaerobe; nonmotile; require amino acids, thiamine and nicotinic acid; when grown anaerobically require uracil and fermentable carbohydrate

$$\text{Glucose} \xrightarrow{\text{absence of oxygen}} \text{Lactic acid}$$

$$\text{Glucose} \xrightarrow{\text{presence of oxygen}} \text{Acetic acid} + CO_2$$

Grow in 15% NaCl or 40% bile & tolerate sodium azide, tellurite, mercuric chloride

5) range 6.5 to 46℃, optimum 35 to 40℃
6) range 4.2 to 9.3, optimum 7 to 7.5
7) skin and mucous membranes

8)

	Coagulase	Mannitol-Acid Anaerobically	α-toxin
S. aureus	+	+	+
S. epidermidi	-	-	-
S. saprophyticus	-	-	-

9) enterotoxin = heat resistant (200-320℃ for 8 to 20 minutes)
usually pigmented yellow to orange.

many beta hemolytic coagulase (+) = pathogenic

produces coagulase, hemolysins, lipases, deoxyribonuclesases, catalase, protease, enterotoxins

10)grow in wide variety of foods

pathogenic – disease in all parts of body

cause food intoxication – ingestion of enterotoxin

11)(a) aerobic plate count on Baird-parker Agar (egg yolk, lithium chloride & tellurite) → tellurium which produces black, shiny, round colonies surrounded by clear zones) -- 35°C for 24h

(b) coagulase test (+)
catalase test (+)
anaerobic use of mannitol & glucose (+)
lysostaphin sensitive (+)
thermostable nuclease (+)

(c) most Probable Number (MPN) = if less than 100 ***S. aureus*** /g suspected – 3 tubes trypticase soy broth with 10% NaCl - 35°C for 48h – streak on Baird-Parker agar & do above biochemicals

(d) enterotoxins (A, B, C, D, E) – microslide diffusion test (see FDA Bacteriological Analytical Manual)

Vibrio

1) *Vibrionaceae*
2) Gram(-)
3) short, straight or curved rods, occasionally S or spiral shaped
4) oxidase (+), respiratory & fermentative metabolism, motile by one polar flagellum or nonmotile, facultative anaerobes, non pigmented or yellow, some need 3% salt, catalase(+)
5) 18 to 37°C optimum
6) 6.0 to 9.0
7) water and alimentary canal
8) ***V. cholerae*** – cholera
   V. parahaemolyticus – food poisoning
9) associated with fish; leading food poisoning in Japan because of raw fish consumption; readily killed by heat
10) food poisoning, especially from raw fish
11) use glucose salt teepol broth and incubate at 37°C for 18h; then streak onto thiosulfate citrate bile salts sucrose agar; confirm by biochemical and serological tests

Yersinia

1) *Enterobacteriaceae*
2) Gram(-)
3) ovoid or rods
4) oxidase (-), catalase (+), lactose not fermented, no gas or H_2S formed, nonmotile at 37°C but motile below 37°C with peritrichous flagella, IMVC (D + - -), KCN not tolerated
5) -2 to 45°C with optimum at 30 to 37°C
6) optimum around 7
7) soil and water
8) ***Y. enterocolitica*** – food-borne illness
   Y. pseudotuberculosis – food-borne illness
   Y. pestis – plague in humans and rodents

Important Molds and Yeasts in Food

Mold

1. morphology

* **hyphae mycelium**----- vegetative & fertile

septa vs. non-septa

"**perfect fungi**"-----both sexual & asexual reproduction,

eg, *Oomycetes* or *Zygomycetes*---nonsepta

Ascomycetes or *Basidiomycetes*---septa

"**fungi imperfecti**"----only asexual reproduction

*asexual spores

(1)conidia 分生孢子

(2)arthrospore 關節孢子

(3)sporangiospore 囊孢子

(4) chlamdospore 厚壁孢子

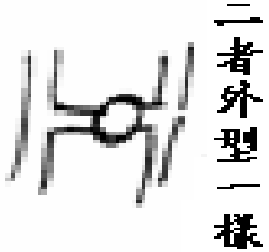
*sexual spores

(1)oospore 卵孢子

有大

有小

(2)zygospore接合孢子



(3)ascospore子囊孢子

2. Physiological characteristics

Aw, temp. mesophile, psychrotrophic, nutrient

3. Important Mold

(A) Enumeration

PDA: potato dextrous agar

MEA: malt extract agar

(1) Plating method:

(a) Acidified medium (pH3.5)

(b)Antibiotic-added medium (chloramphenicol and / or chlortetracycline)

.dichloran: inhibit spreading

.sodium thiosulfate

.sodium tetrathionate reduce effect of heavy metal toxicity.

(2) microscopic methods: enumerate mold filaments in canned fruit & vegetables.

(3) Indirect methods

(B) Role of fungi in food

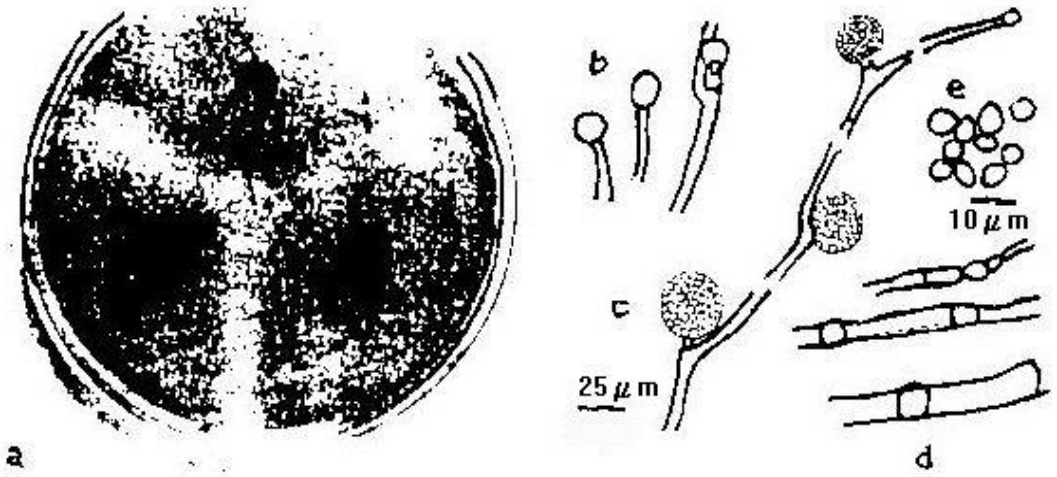
- Spoilage
- Health hazards (mycotoxins)
- fermentation

(C) Molds important in foods

(1) Zygomycetes 接合菌綱，完全菌〈具有性世代及無性世代〉，菌絲無隔膜，生長快速。

.***Mucor*** -糖化菌，Starch→單糖　*M. miehei*: lipase production

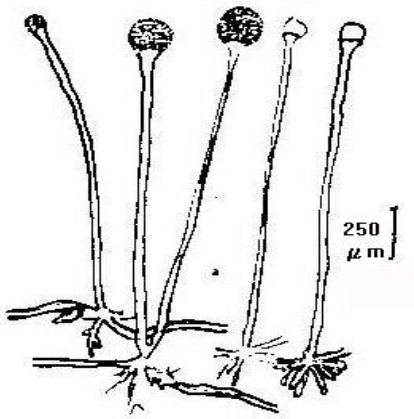
M. rouxii: amylase production

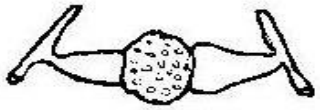


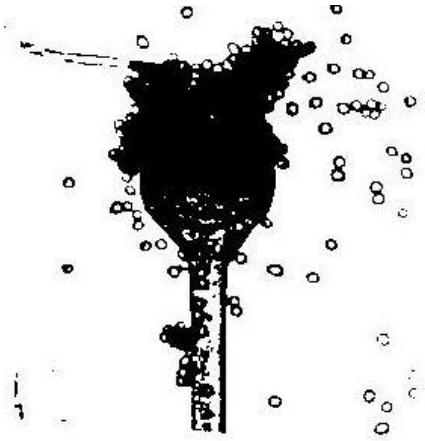
Rhizopus -類似 *Mucor*，有Rhizoid，亦為糖化菌一種

R.stolonifer: bread mold

R.oligosporus: Tempeh

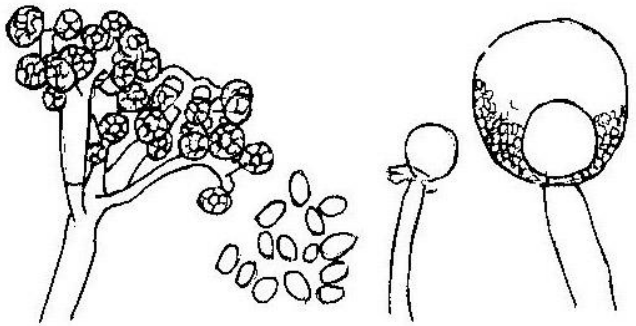






***Thamnidium*一枝黴，長期冷藏肉之表面之黑點**

T. elegans: “Whisker” of beef in cooler



(2)***Ascomycetes***子囊菌綱

.Byssochlamys

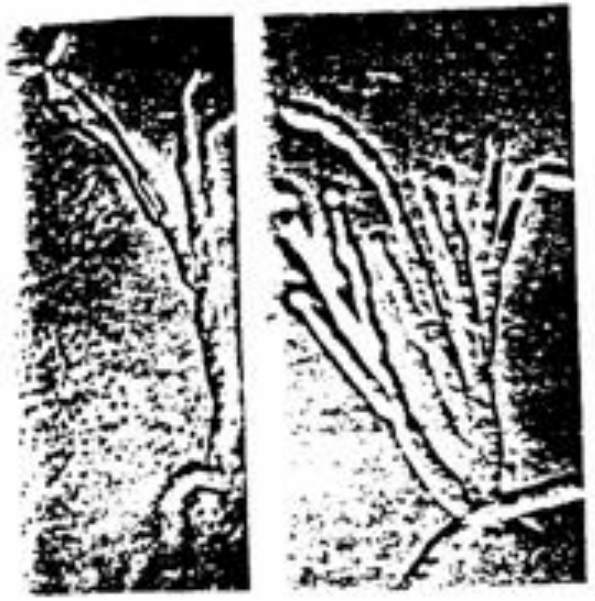
Some spores heat resistant → survive heating processing

growth in reduced O_2 → produce pectic enzyme → soft texture of canned

& fruits → spoilage

B. fulva : heat resistant spore

(survive for 5 h at 88°C)



.***Claviceps***

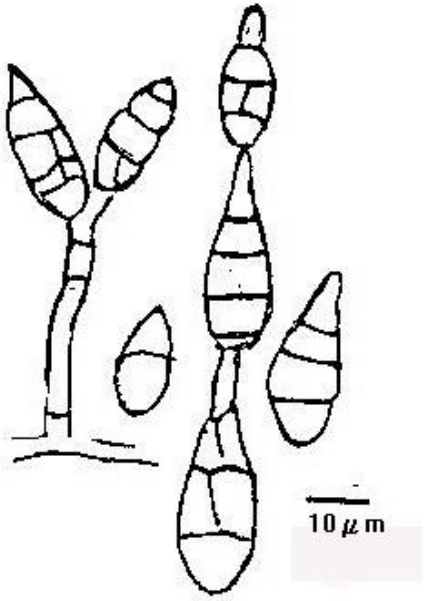
C. purpurea produce alkaloid toxin(ergot) on cereals→ hallucinations(幻覺)

“St. Anthony’s fire”

.***Neurospora***營養需求低，遺傳及生化研究工具

(3)**Deuteromycetes** 不完全菌綱，只有無性世代

. ***Alternaria*** 互生子菌屬



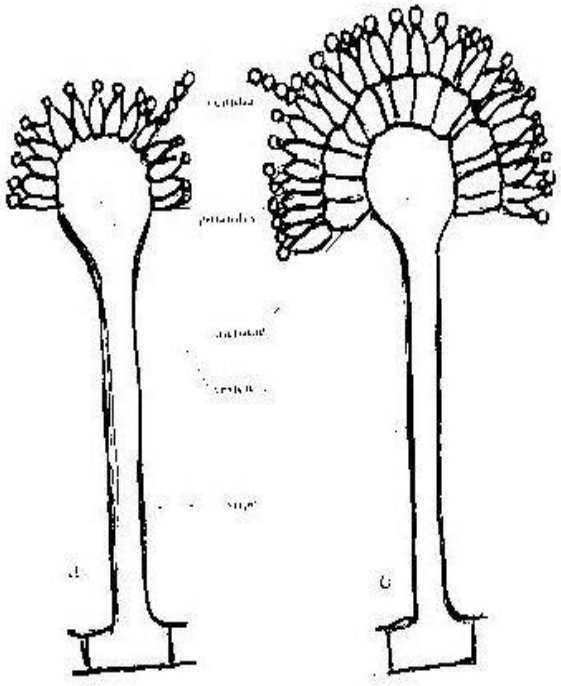
黑色孢子

plant pathogens

spoilage of tomato in the field

A.alternate produce mycotoxins (alternarin)

.*Aspergillus* 麴黴



A. niger: black conidia,citric acid.

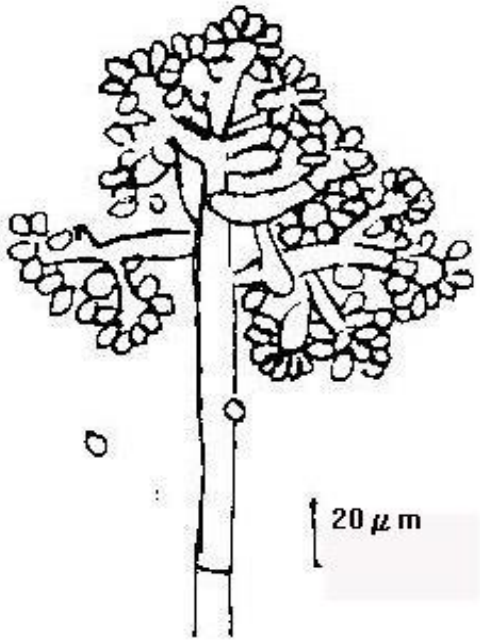
A. flavus & ***A.parasiticus***: yellow-green

A. candidus: white conidia

A. ochraceus: yellow-brown conidia,dry food ochratoxin.

A. oryzae: sake, soy sauce, miso production.

.*Botrytis* 蠶絲菌屬



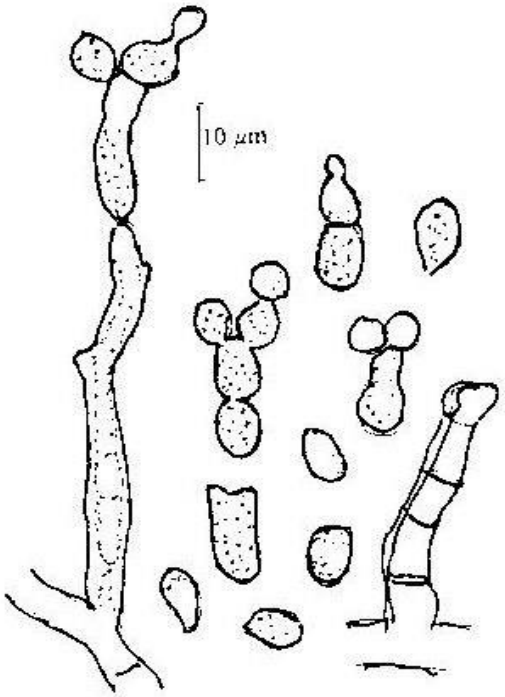
B. cinerea

如樹枝狀分支

灰色

fruit & vegetable spoilages

.*Cladosporium* 分枝黴菌

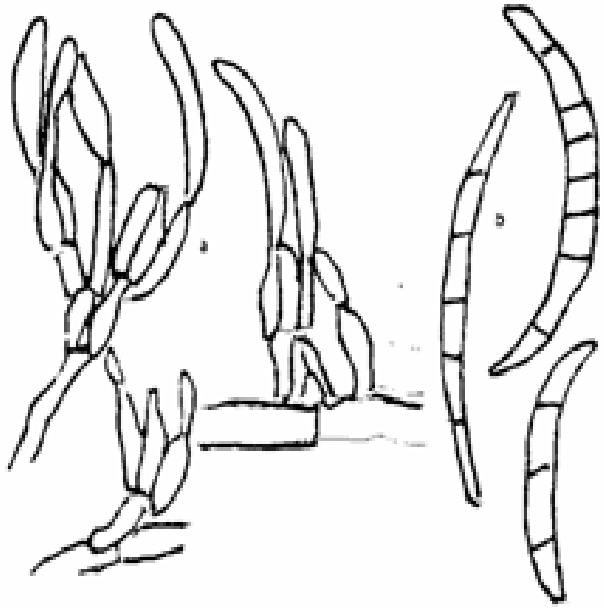


分隔，由之產生厚膜孢子

C. herbarum:“black spot”on beef, cheese

C. cladosorioides: grains, flour, vegetable

.*Fusarium* 鐮刀黴菌屬



plant pathogens

F.moniliforme:gibberellic acid

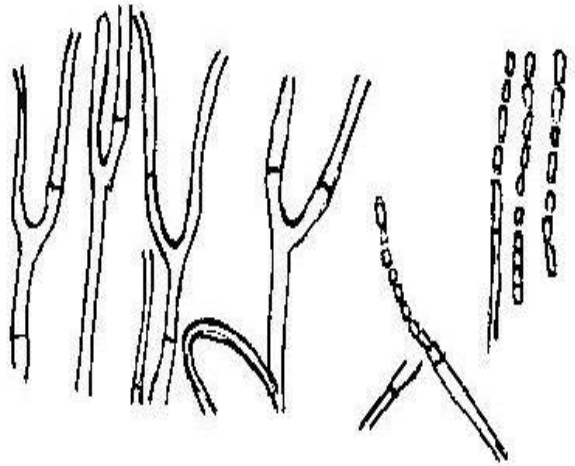
一種植物生長激素

F.oxysporium

F.roseum Zearalenone

F.tricintcum (mycotoxin)

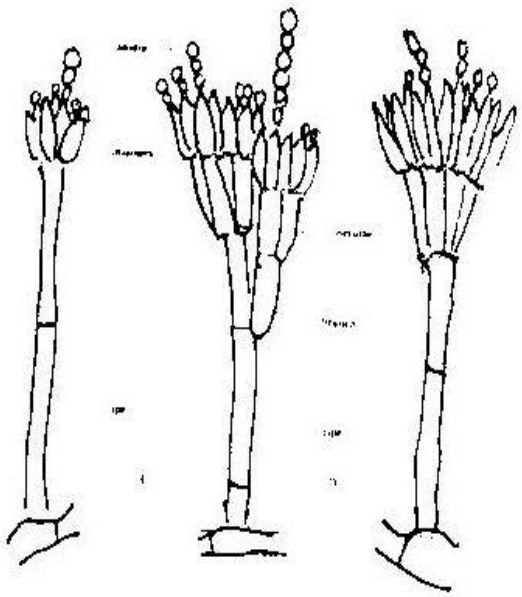
.*Geotrichum*



yeastlike,white

G. candidum: machinery mold.

.*Penicillum* 青黴菌屬



P.chrysogenum: produce gluconic acid, protease, penicillin.

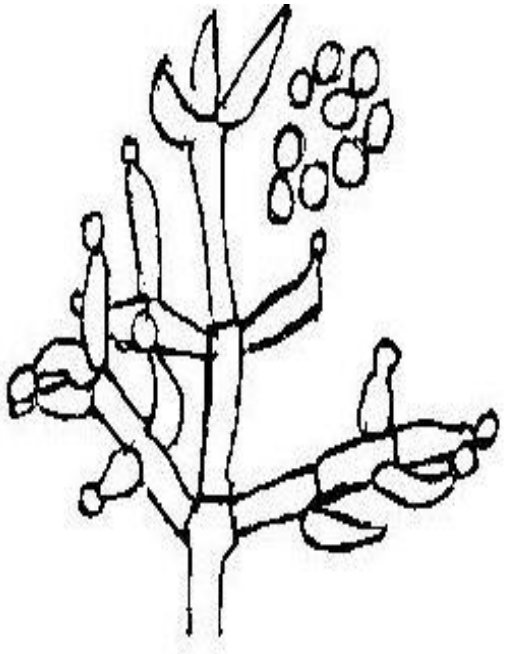
P.camemberti: Camembert cheese

P.cyclopium: penicillic acid (mycotoxin)

P.viridicatum: citrinin ochratoxin

P.expansum: patulin (apple)

. *Trichoderma*



T. viride

T. roseum:cellulolytic

Yeasts

有性生殖-接合生殖

無性生殖-分裂，出芽生殖

菌落多為黃色，少數褐、灰，(粉)紅

(1) ***Ascomycetes*** :有性生殖及無性生殖均有

.*Debaryomyces*

D. hanasenii: highsalt tolerance.(18~21%salt)

film forming yeast in brine

slime on salted meats

spoilage of orange juice, yogurt,cheese,wine,...

.*Hanseniaspora*

inositol & pantothenate: growth factor.

can be used to assay for these compounds.

.*Hansenula*

assimilate nitrate.

pseudomycelium or true mycelium may be formed.

.*Kluyveromyces*

can use lactose

whey→alcohol by ***Kluveromyces***

.*Pichia*

film forming yeast on liquid media or brine.

budding & from pseudomycelium.

.*Saccharoymyces*

sugar fermentation, not use lactose & nitrate.

S. cerevisiae & ***S. uvarum***

S. rouxii: osmophilic yeast,soy sauce.

S. bailii: xerotolerant

S. bisporus: xerophilic