



Food Microbiology

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How to read this chapter

1. **Food spoilage microorganisms:** familiar the Genus name and its characteristics
2. **Food-borne pathogens:** should know its scientific name (Genus+species) and significance in food/human
3. **Industrial important microorganism:** should know its scientific name and role in industry

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°C range with 20 to 30°C 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* species; 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



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°C, some grow at 4°C and none at 45°C
- 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)



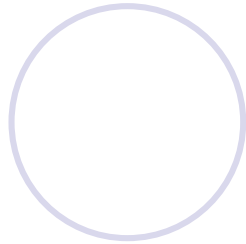
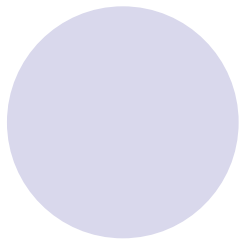
Acetobacter

- 1) *Acetobacteraceae*
- 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°C with 25-30°C 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 rosy 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

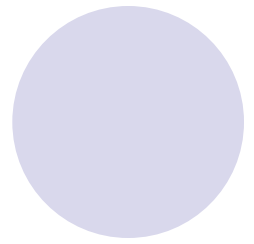
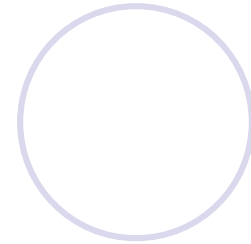
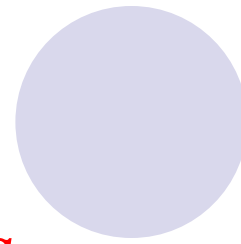


Arthrobacter

- 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 thermotolerant**
- 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°C with 30°C optimum, reduces nitrate to nitrite, **cause roty bread**, rancid salad dressing & used to manufacture amylases & proteases

B. cereus – temp. 10 to 45°C with optimum of 30°C, 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°C for 3 minutes)

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

B. coagulans – temp. 15 to 60°C, pH 4.0 to 6.0 optimum, spores (121°C for 0.7 minutes to destroy), “**flat sour**” in canned foods(平酸罐), 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** (非常耐酸及耐熱)
- Guaiacol (2-methoxyphenol) and halophenols (2,6-bromophenol, 2,6-chlorophenol) were identified as the **offensive smelling agent** in many *Alicyclobacillus* spp. related spoilage. (造成濃縮果汁異味的主要菌屬)

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°C
- 6) optimum 6 to 7 with little growth below pH 5.5
- 7) **alimentary and intestinal 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 affiliation)
- 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°C
- 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 from 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% O₂ and 10% CO₂**
- 10) **food gastroenteritis from water**, raw milk, undercooked pork and poultry
- 11) complex, see current literature



- 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 ($\text{CO}_2 + \text{H}_2$), IMVC ($\pm + - +$)
- 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, one of coliform groups
- 10) spoils fresh meat & poultry
- 11) same as for *Escherichia*



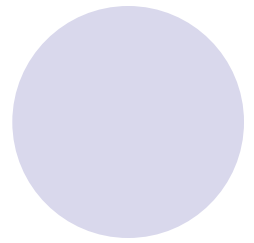
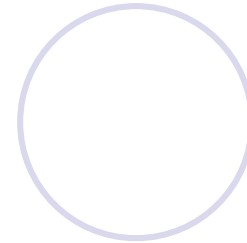
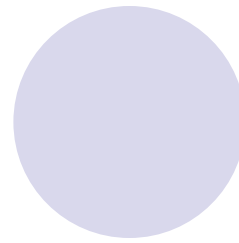
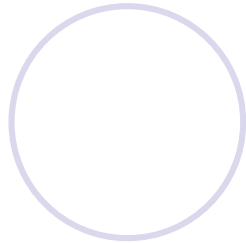
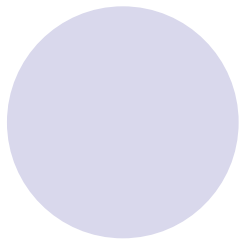
Clostridium

- 1) *Bacillaceae*
- 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. 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 from 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



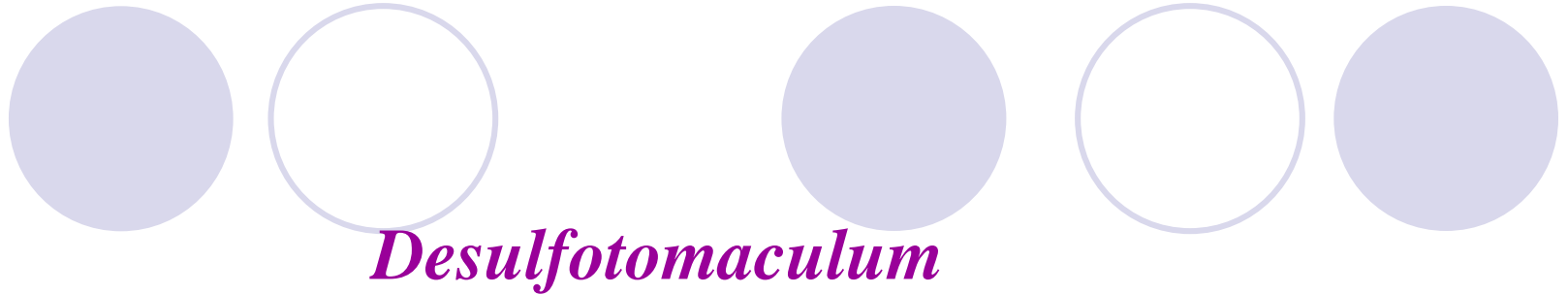
C. perfringens – optimum temp. 45°C, nonmotile, require amino acids and growth factors, pH 5 to 8, H₂S produced in most media, spores need minutes to 6h at 100°C for inactivation, **produced toxin** (α -in US) in intestine from cooked meat and related foods causes food poisoning

C. thermosaccharolyticum – obligate thermophile with optimum at 55°C, **thermophilic anaerobe (TA)** causing **hard swell** (彈跳罐，膨罐的一種) in non-acid canned foods, coagulates milk, degrades sugar

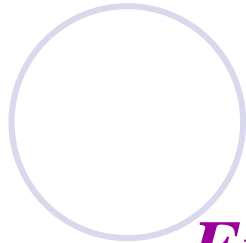
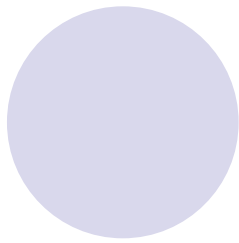


Corynebacterium

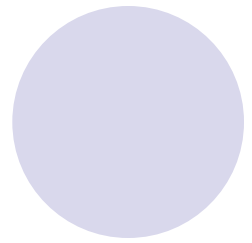
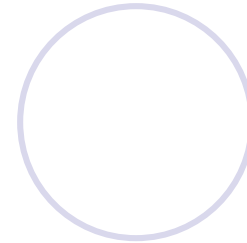
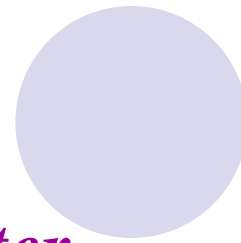
- 1) Coryneform Group
- 2) **Gram(+)** – can lose stain easily and only granules remained
- 3) straight and curved rods frequently showing club-shaped swelling, produce palisade layers
- 4) catalase (+), facultative anaerobic or aerobic, non-motile or motile
- 5) 0 to 40°C
- 6) 5 to 7.5
- 7) soil, water, air, plants, intestinal tract
- 8) *C. bovis* – mastitis in cows
C. diphtheriae – diphtheria – may be transported by food
- 9) Most mesophiles, some psychrotrophs
- 10) *Corynebacterium* species – 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



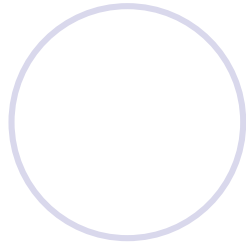
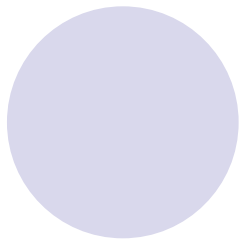
- 1) *Bacillaceae*
- 2) **Gram(+)**
- 3) straight or curved rods with rounded ends, single or sometimes in chains; **spores** are oval to round, terminal to subterminal, and cause swelling of cells
- 4) anaerobic, catalase (-), sulfate reduced to sulfide, respiratory metabolism, motile by peritrichous 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 H₂S;
thermophilic sporeformer
- 10) causes **sulfate spoilage of canned foods** (peas, corn)(硫臭罐)
- 11) use anaerobic conditions and thermophilic temperatures



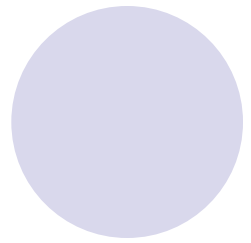
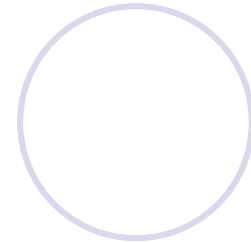
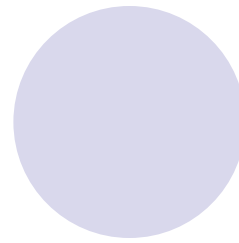
Enterobacter



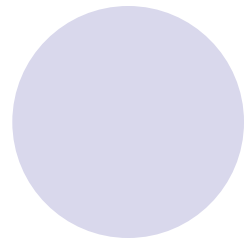
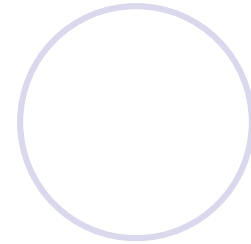
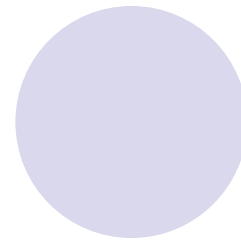
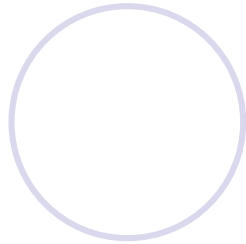
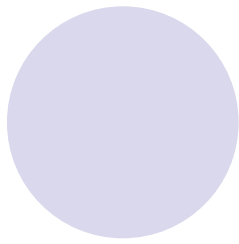
- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) short rods
- 4) catalase (+), oxidase (-), no H₂S, IMVC (---++), acid & gas by 2,3 butanediol fermentation, motile by peritrichous flagella, citrate & acetate used as sole carbon
- 5) optimum 30 to 37°C
- 6) 4.5 to 8.5
- 7) plants, soil, water & sometimes intestinal tract
- 8) *E. aerogenes* – roty 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

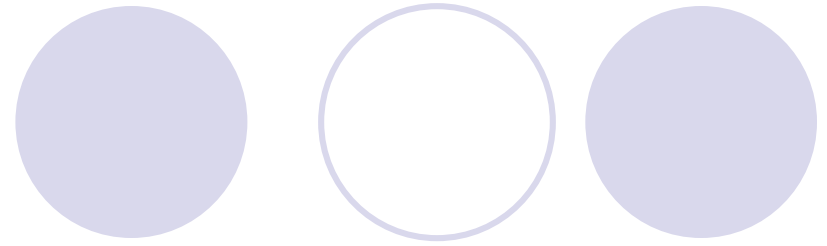
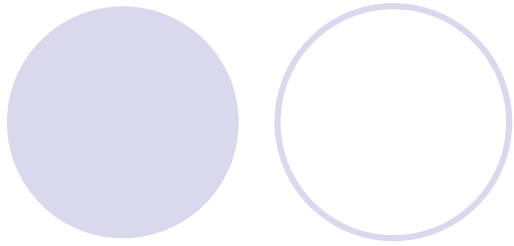


- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) single straight rods
- 4) catalase (+), oxidase (-), acid but gas weak or absent, facultative anaerobes, motile by peritrichous flagella, **degrade pectins**, rarely produce urease or lipases, pigment yellow to red
- 5) optimum 27-30°C, range 1 to 40°C
- 6) 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°C optimum 30 to 37°C
- 6) 4.5 to 8.5
- 7) intestinal tract



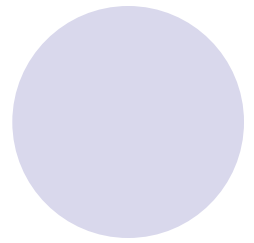
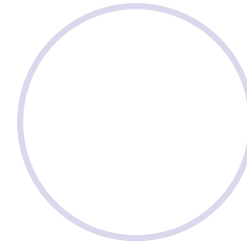
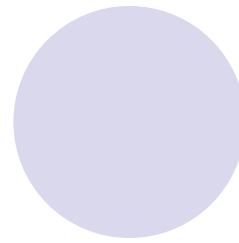
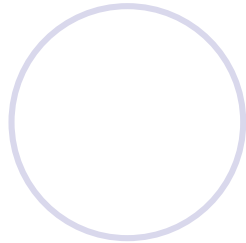
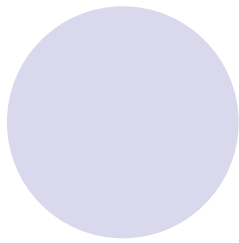
8) *E. coli*

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

9) used as fecal indicator for water foods

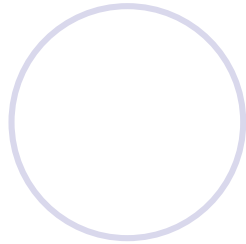
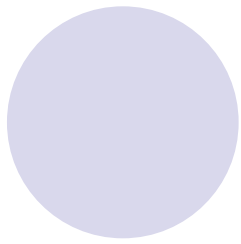
10) spoils meat, poultry, fish, eggs, dairy products; EEC causes diarrhea food poisoning especially in infants and travelers; ETEC causes traveler's diarrhea; *E. coli* O157:H7 causes hemorrhagic colitis

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

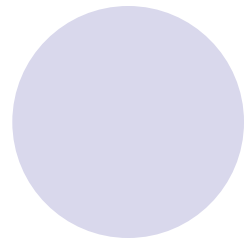
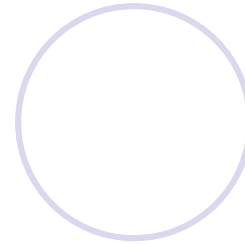
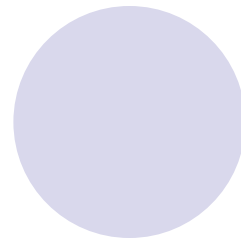


Flavobacterium

- 1) Genera of uncertain affiliation
- 2) Gram (+)
- 3) coccibacilli to slender rods
- 4) respiratory metabolism, motile by peritrichous 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*



Klebsiella

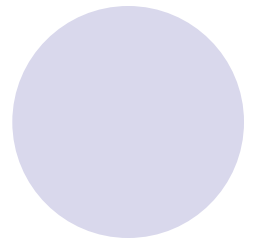
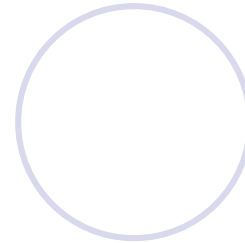
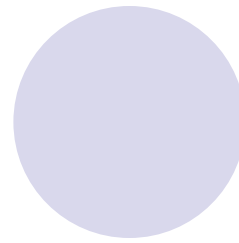
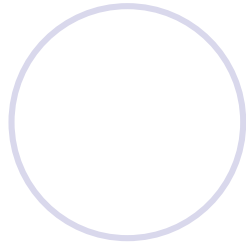
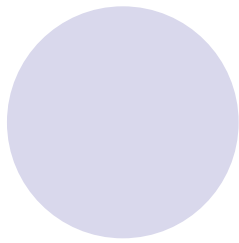


- 1) *Enterobacteriaceae*
- 2) Gram (-)
- 3) capsulated rods – single, pairs or chains
- 4) oxidase (-), catalase (+), acid & gas by 2,3 – butanediol fermentation, H₂S not produced, nonmotile, IMVC (D,D,D,D), resistant to penicillin
- 5) optimum 35 to 37°C
- 6) optimum 7.2
- 7) respiratory and intestinal 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 O₂ and 5 to 10% CO₂), motile by peritrichous flagella (20 to 25°C), 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, H₂S(-), O- and H-antigens used to differentiate serotypes, grows in 10% salt
- 5) range of 2.5 to 38°C; optimum 35 to 37°C
- 6) pH range 5.5 to 9.6
- 7) feces of animals and humans, vegetation, silage, soil

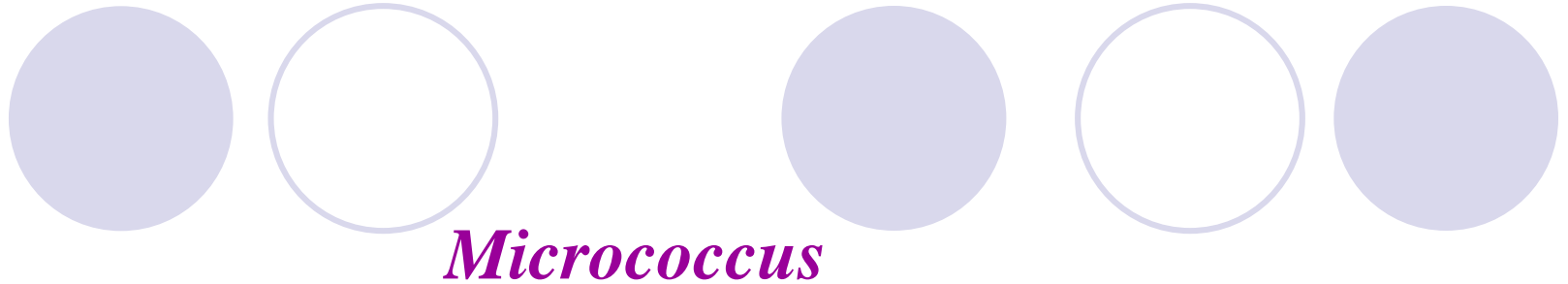


8) *L. monocytogenes*

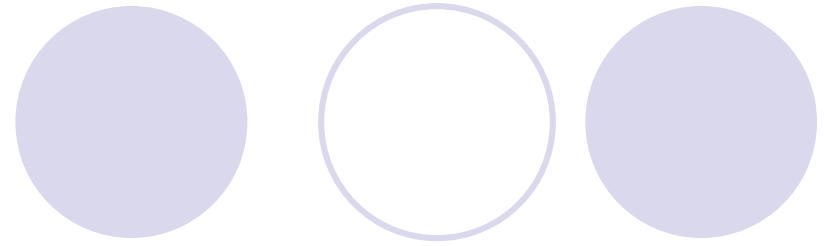
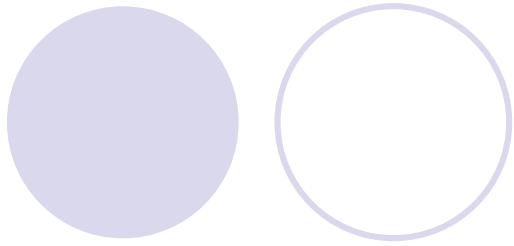
9) able to grow at refrigeration temperatures, produces gastroenteritis and leukocytosis and monocytosis (mild influenza-like illness to meningitis, bacteremia endocarditis, and central nervous system infection; many patients have other medical disorders or are on immunosuppressive drugs) with a mortality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

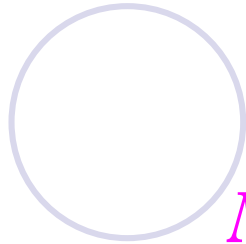
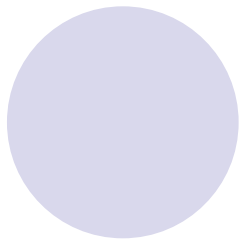


- 1) *Micrococcaceae*
- 2) **Gram (+)**
- 3) cocci-irregular clusters, single or pairs
- 4) catalase (+), tolerates 5-15% salt, water soluble pigment (yellow, orange & red), lysostaphin (-), nonmotile, strict aerobe
- 5) optimum = 25-30°C, range = 0 to 45°C
- 6) range = 5 to 8.5
- 7) fresh & salt water, 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-- thermotolerant
M. radiodurans/irradiation-- resistant to

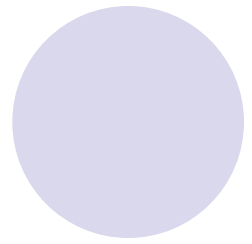
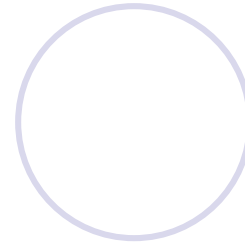
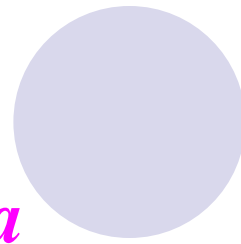


9) selective advantage:

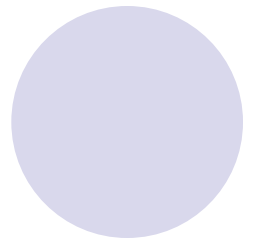
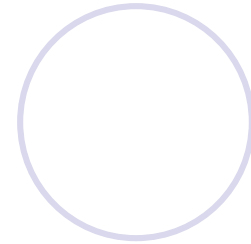
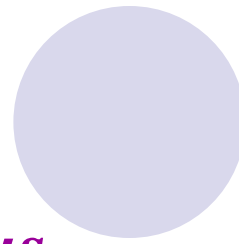
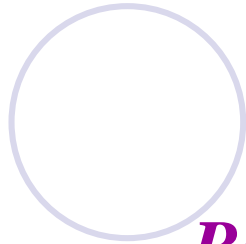
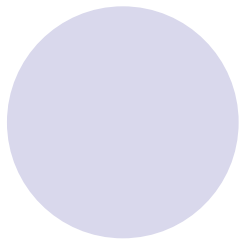
- (a) **high salt foods**
- (b) use nitrate ion in place of oxygen – cured meats
- (c) **survive heating – milk pasteurization,**
- (d) more resistant to dehydration & radiation
- (e) sensitive to acid – inhibited at pH 5
- (f) **grow at refrigeration temperatures**
- (g) produce lipolytic & proteolytic 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.



Moraxella

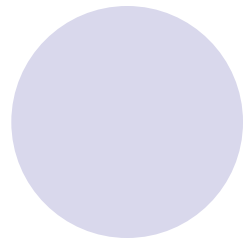
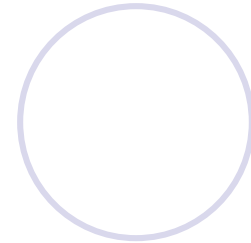
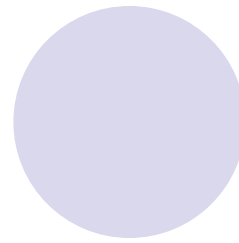
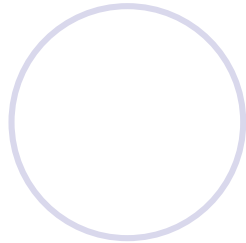
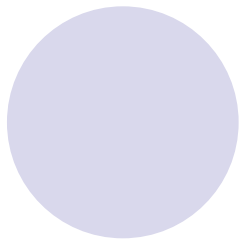


- 1) *Neisseriaceae*
- 2) Gram(-)
- 3) short plump rods often approaching cocci; in pairs or chains
- 4) oxidative metabolism, strict aerobes, oxidase (+), catalase (+), sensitive to penicillin, no flagella but may have twitching motility on solid surfaces, carbohydrates not utilized
- 5) 32 to 35°C optimum
- 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*



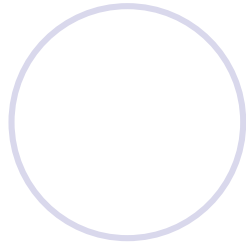
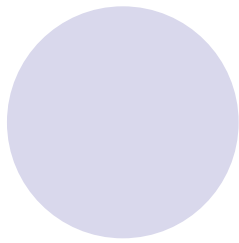
Pediococcus

- 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*

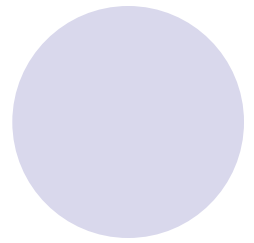
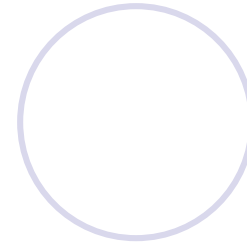
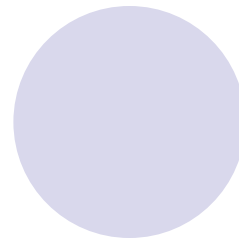


Propionibacterium

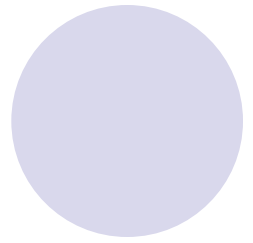
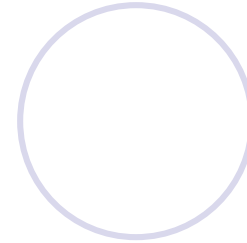
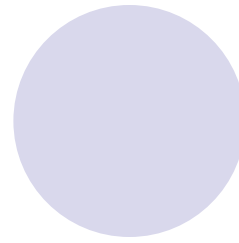
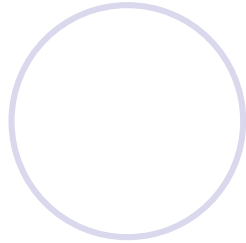
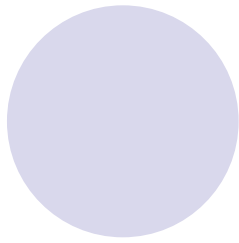
- 1) *Propionobacteriaceae*
- 2) **Gram(+)**
- 3) nonsporeforming, pleomorphic, diptheroid (club-shaped) rods
- 4) **anaerobic to aerotolerant**, fermentative yielding propionic and acetic acids and carbon dioxide, catalase (+)
- 5) optimum 30 to 37°C
- 6) optimum pH 7.0
- 7) dairy products and intestinal 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% CO₂ 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°C
- 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**

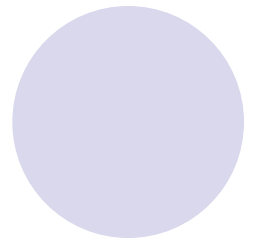
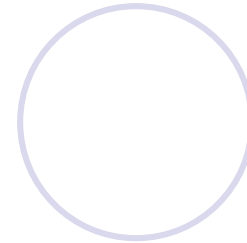
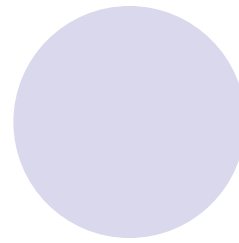
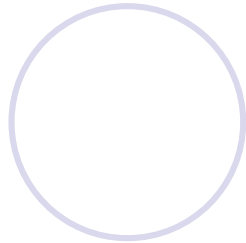
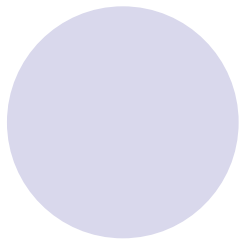
10) **spoilage of meats, poultry seafood, eggs, dairy products**

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 source, oxidase (-), produces H₂S, IMVC (- + - +), mixed acid fermentation (lactic, formic acetic & succinic), catalase (+)
- 5) 7 to 47°C with optimum at 37°C
- 6) 4-9 with optimum at 6.5 to 7.5
- 7) intestinal tract



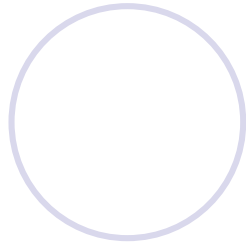
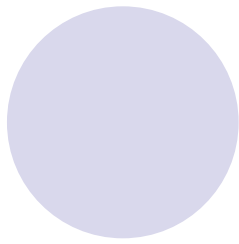
8) ***S. typhi*** – typhoid fever

S. typhimurium – most often in food poisoning outbreaks

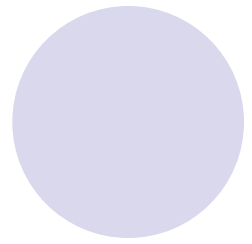
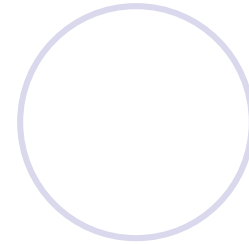
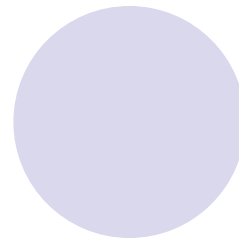
9) **causes food infection** due to ingestion of large number of cells, classified by serology (O, K, and H antigens)

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

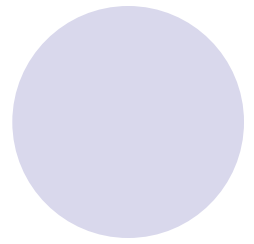
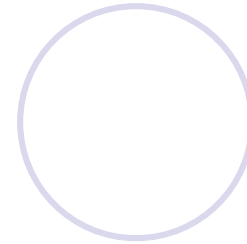
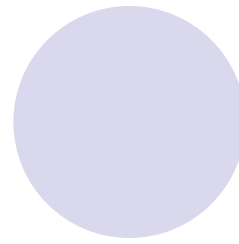
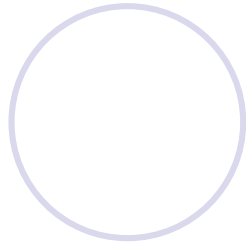
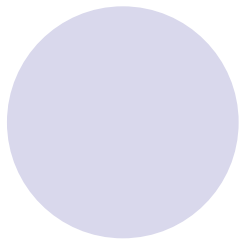
11) use pre-enriched lactose broth for 24h 35°C followed by selective enrichment in selenite-cystine and tetrathionate broths; streak on selective agars (Hektoen enteric, xylose lysine desoxycholate, bismuth-sulfite); characterize by biochemistry (TSI, LIA urease, etc.) and serology (O, H, K antisera)



Serratia

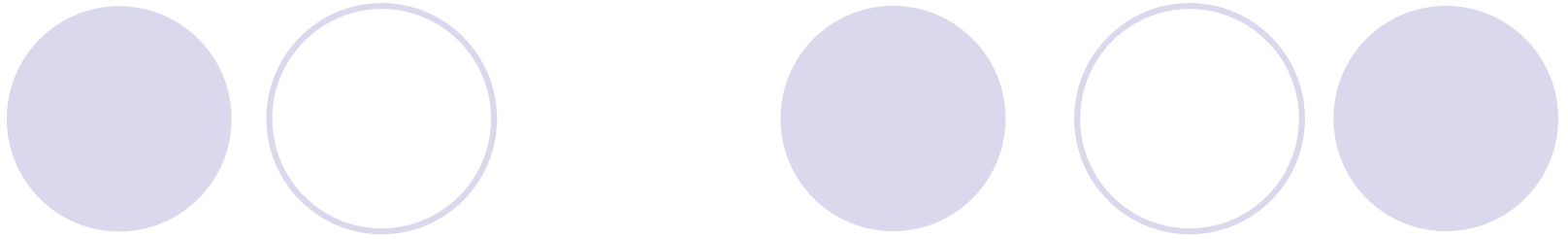


- 1) *Enterobacteriaceae*
- 2) Gram (-)
- 3) rods-some encapsulated
- 4) catalase (+), oxidase (-), many strains produce pink to red pigments, IMVC (- + D +), glucose may or may not be fermented with gas production, lactose not fermented
- 5) optimum 25 to 30°C
- 6) optimum around 7
- 7) soil and water
- 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*

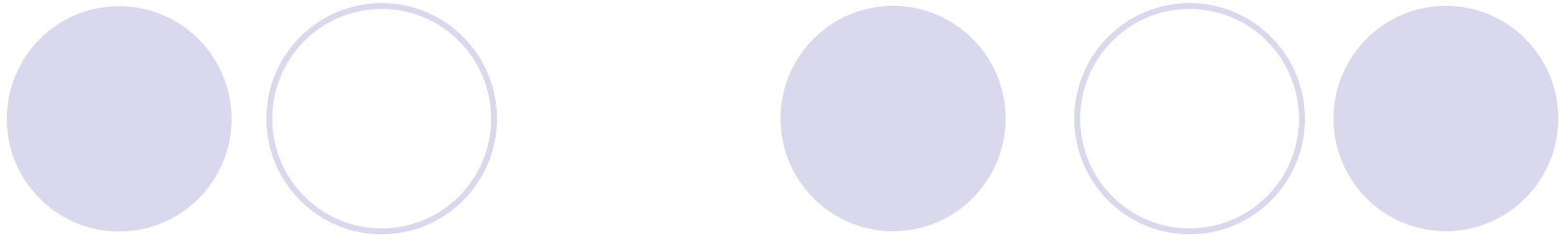


Shigella

- 1) *Enterobacteriaceae*
- 2) Gram (-)
- 3) short rods
- 4) acid but not gas from carbohydrates, oxidase (-), catalase (\pm), nonmotile, inhibited by KCN, H_2S not produced, IMVC (D + - -), aerobic
- 5) optimum 37°C
- 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

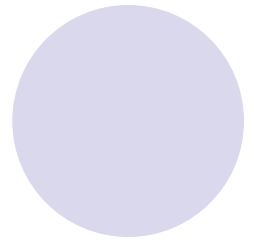
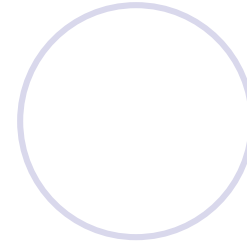
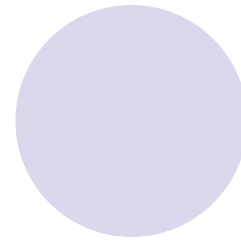
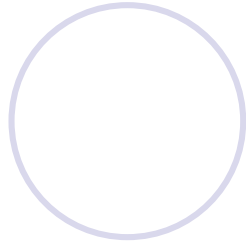
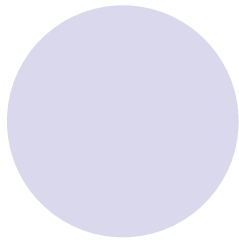


- 10) cause dysentery when transmitted by water and food
- 11) use gram-negative broth followed by selective agars
(low=MacConkey or Tergitol 7 Agar;
intermediate=Xylose-Lactose-Desoxycholate (XLD);
high=Salmonella-Shigella Agar or Hektoen Enteric Agar);
confirm by biochemical tests and serology



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°C; 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)

	<u>Pyogenic</u>	<u>Viridans</u>	<u>Enterococcus</u>	<u>Lactococcus</u>
10°C	-	-	+	+
45°C	-	+	+	-
pH 9.6	-	-	+	-
6.5 % NaCl	-	-	+	-
	<i>S. agalactiae</i>	<i>S. thermophilus</i>	<i>S. faecium</i>	<i>S. lactis</i>
	<i>S. pyogenes</i>		<i>S. faecalis</i>	<i>S. cremoris</i>

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 – indicators of fecal contamination, thermotolerant, grows 5 to 50°C, proteolytic, produces acid in pickles and sauerkraut

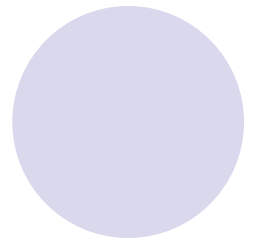
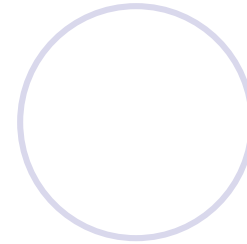
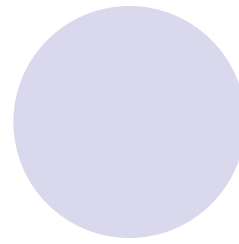
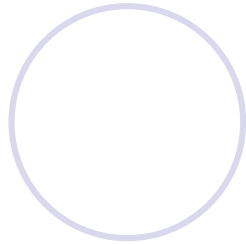
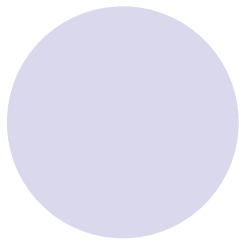
S. faecium – common in plants, thermotolerant

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°C

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

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



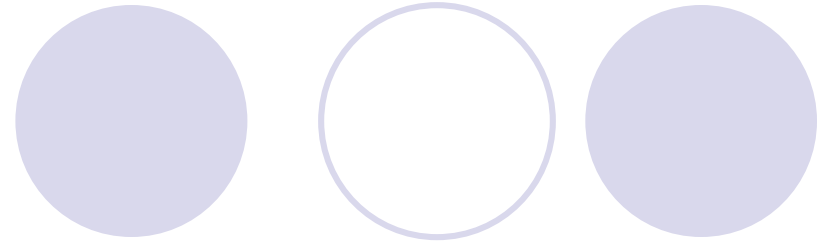
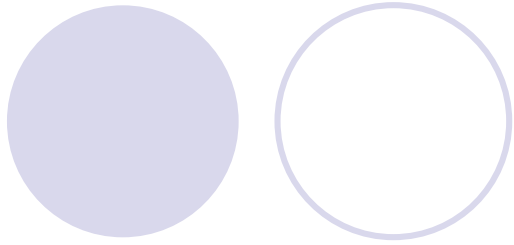
Staphylococcus

- 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

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

Glucose $\xrightarrow{\text{presence of oxygen}}$ Acetic acid + CO₂

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



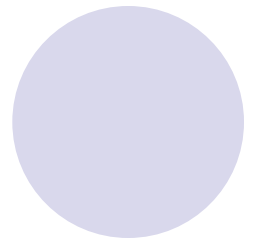
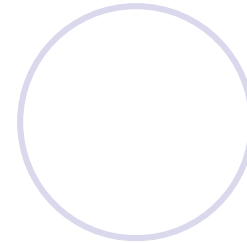
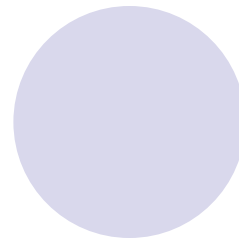
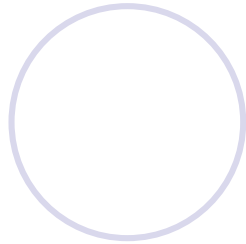
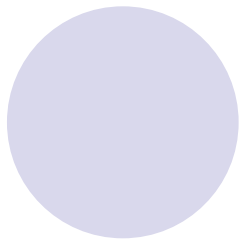
5) range 6.5 to 46°C, optimum 35 to 40°C

6) range 4.2 to 9.3, optimum 7 to 7.5

7) skin and mucous membranes

8)

	<u>Coagulase</u>	Mannitol-Acid <u>Anaerobically</u>	<u>α-toxin</u>
<i>S. aureus</i>	+	+	+
<i>S. epidermidi</i>	-	-	-
<i>S. saprophyticus</i>	-	-	-



9) **enterotoxin = heat resistant (200-320°C for 8 to 20 minutes)**

usually pigmented yellow to orange.

many beta hemolytic coagulase (+) = pathogenic

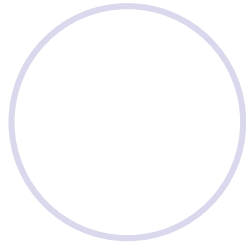
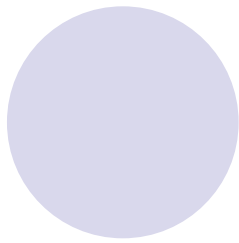
produces coagulase, hemolysins, lipases,

deoxyribonucleases, catalase, protease, enterotoxins

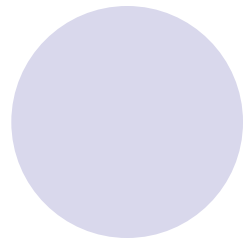
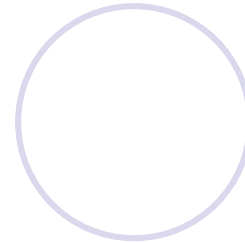
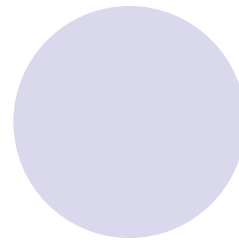
10) grow in wide variety of foods

pathogenic – disease in all parts of body

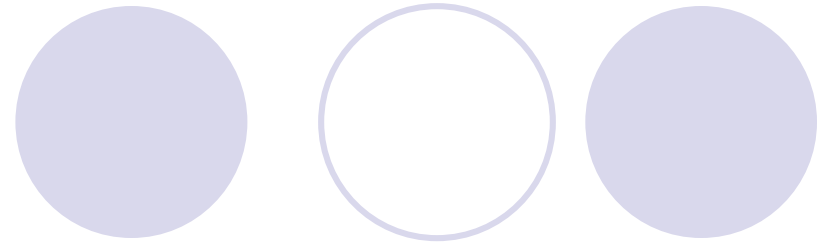
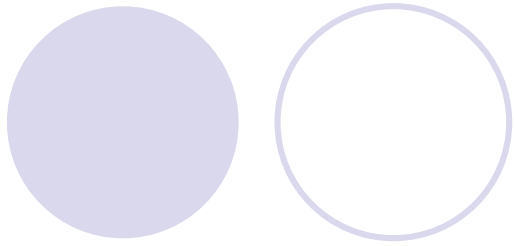
cause food intoxication – ingestion of enterotoxin



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 H₂S 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



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)

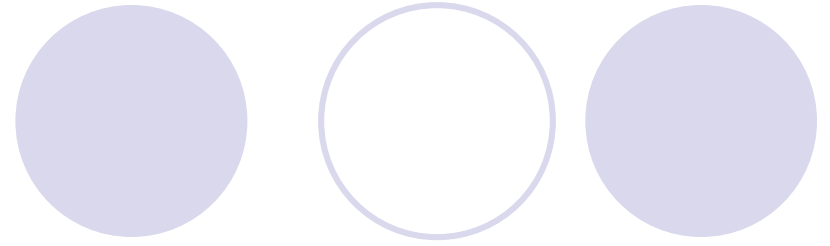
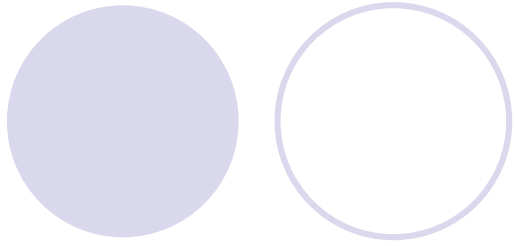
.dichloran: inhibit spreading

.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

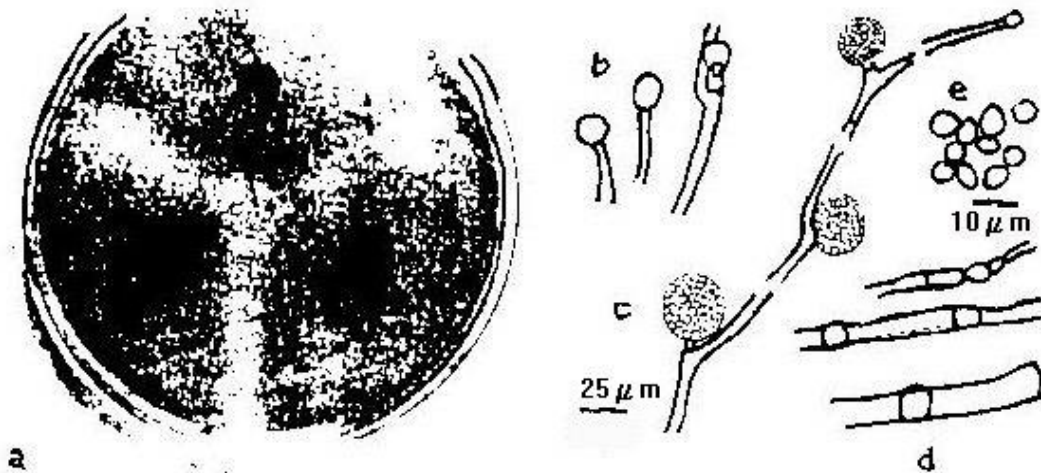
- Spoilage
- Health hazards (mycotoxins)
- fermentation

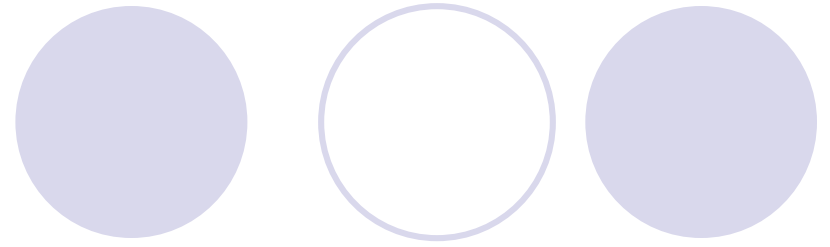
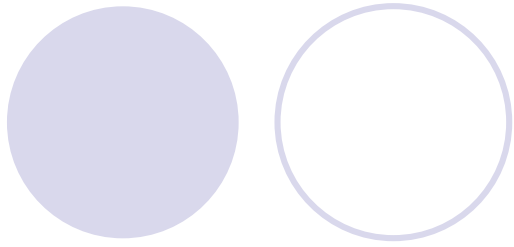
(C) Molds important in foods

(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

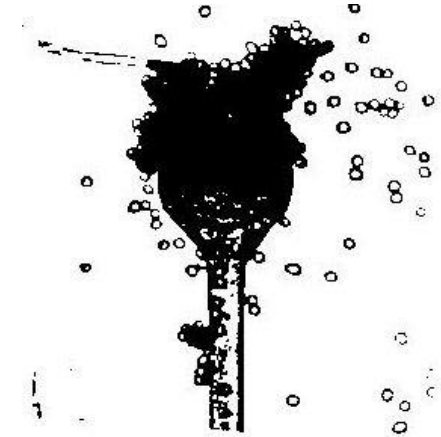
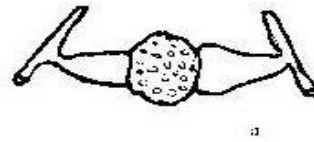
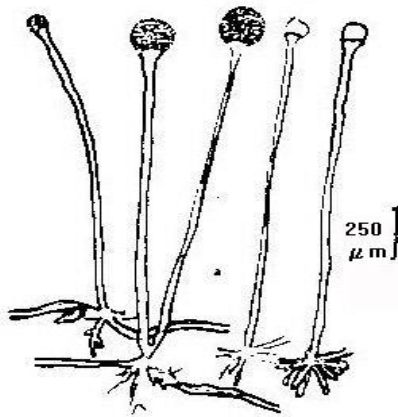
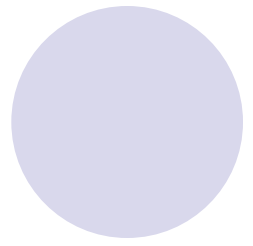
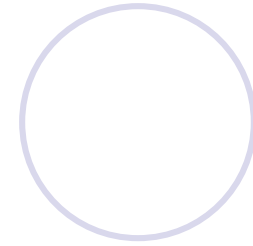
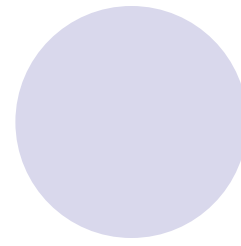
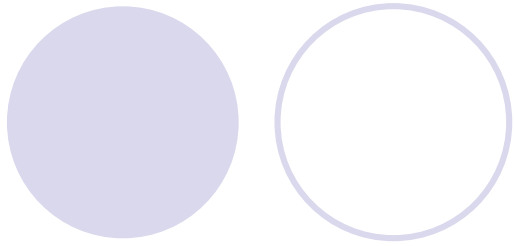




Rhizopus -類似 *Mucor*，有Rhizoid，亦為糖化菌一種

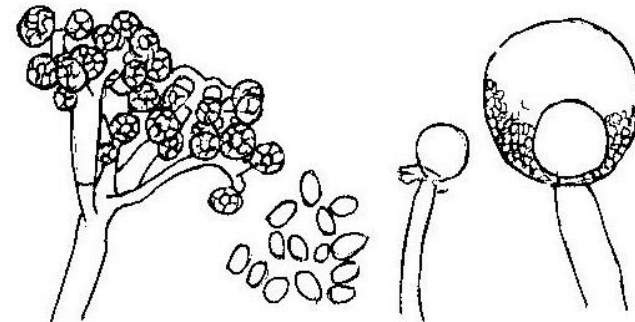
R.stolonifer: bread mold

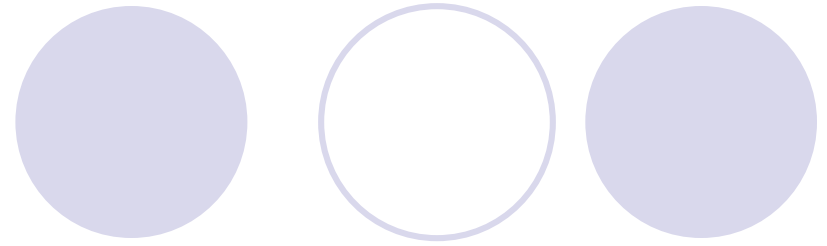
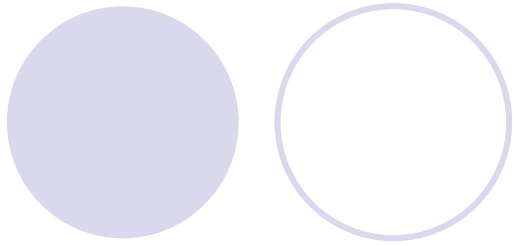
R.oligosporus: Tempeh



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 O₂ → produce pectic enzyme → soft texture of
canned

& fruits → spoilage

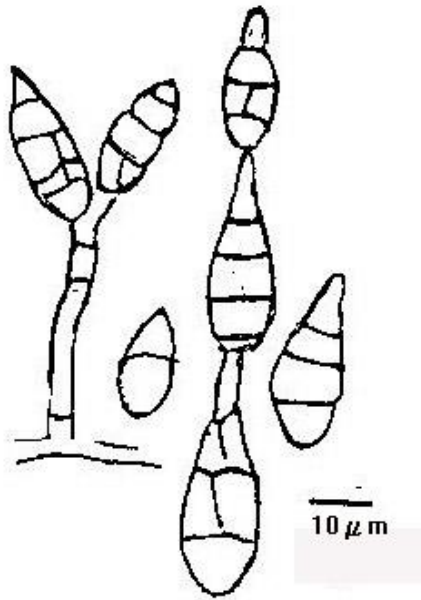
B. fulva : heat resistant spore

(survive for 5 h at 88°C)



(3) **Deuteromycetes** 不完全菌綱，只有無性世代

• *Alternaria* 互生子菌屬



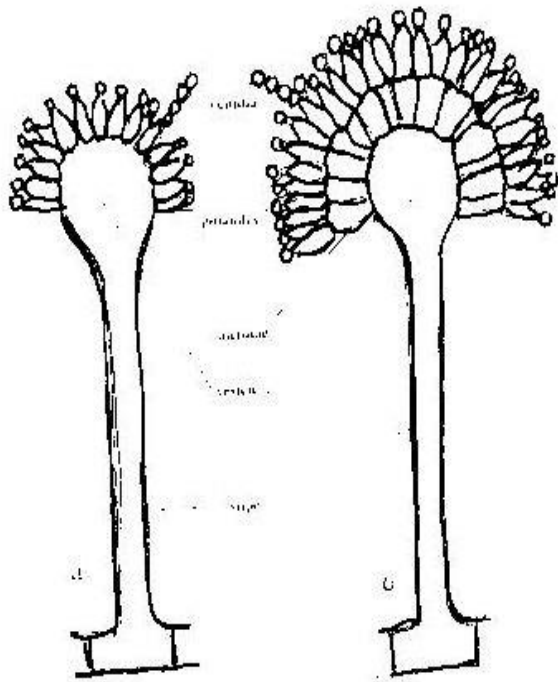
黑色孢子

plant pathogens

spoilage of tomato in the field

A.alternate produce mycotoxins (alternarin)

Aspergillus 麴黴



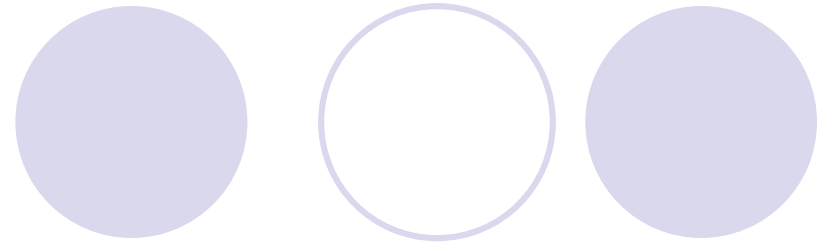
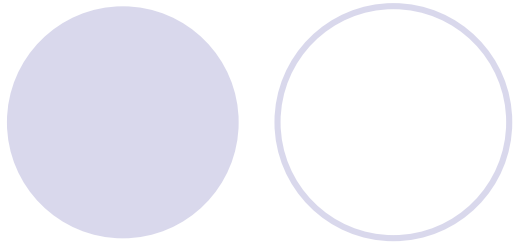
A. niger: black conidia, citric acid.

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

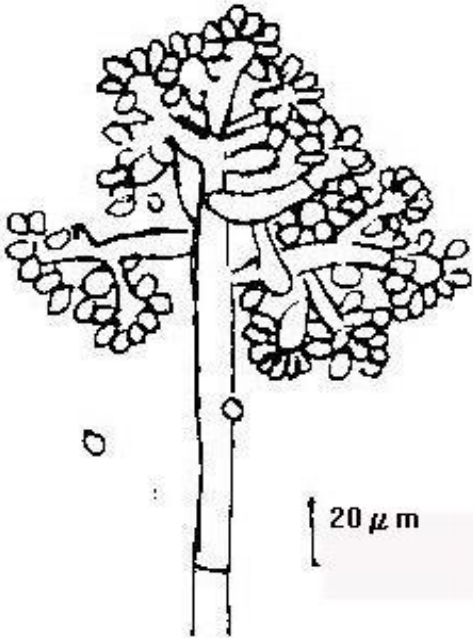
A. candidus: white conidia

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

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



.Botrytis 蠹絲菌屬



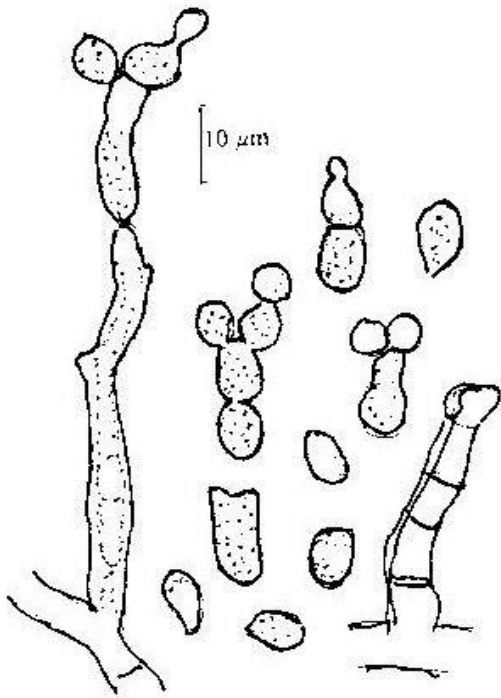
B. cinerea

如樹枝狀分支

灰色

fruit & vegetable spoilages

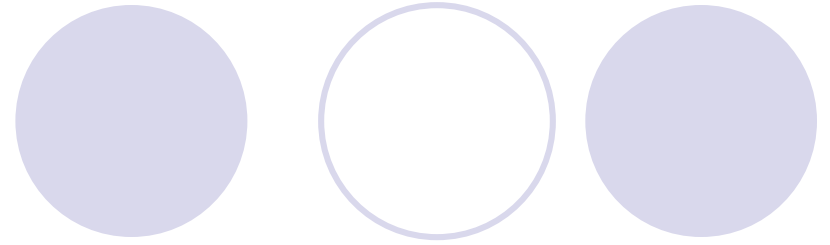
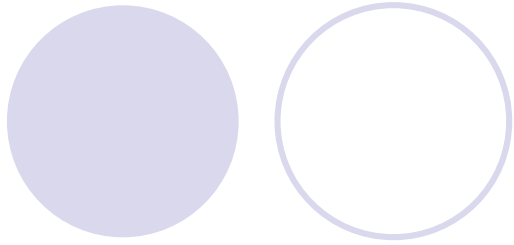
.Cladosporium 分枝黴菌



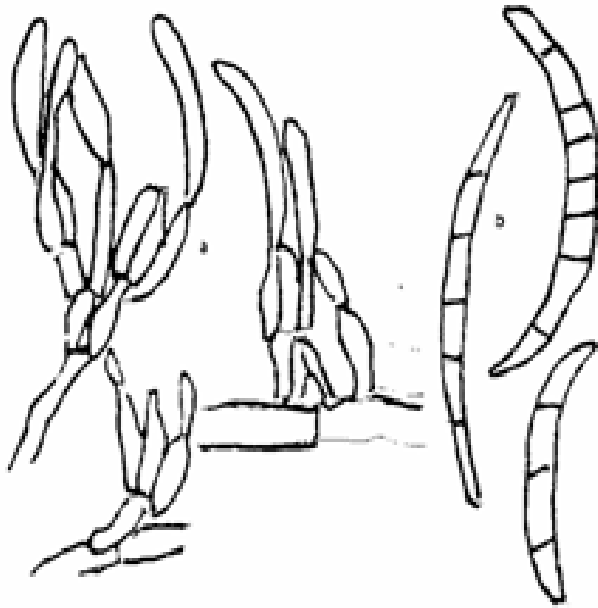
分隔，由之產生厚膜孢子

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

C. cladosporioides: grains, flour, vegetable



Fusarium 镰刀菌属



plant pathogens

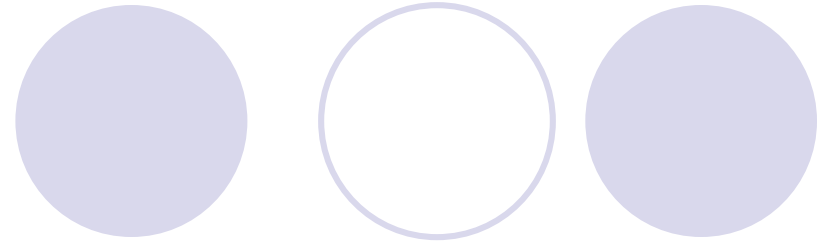
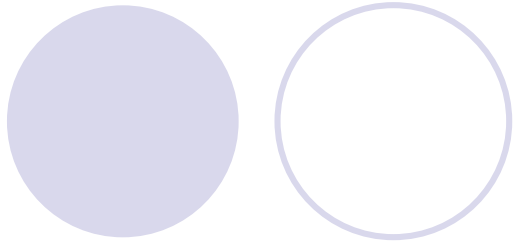
F.moniliforme: gibberellic acid

一種植物生長激素

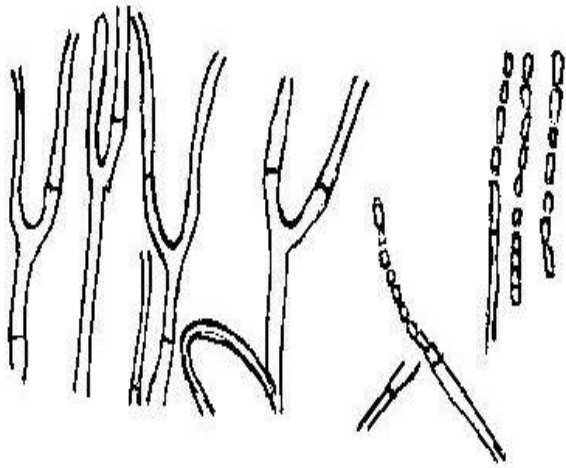
F.oxysporium

F.roseum Zearalenone

F.tricinctum (mycotoxin)



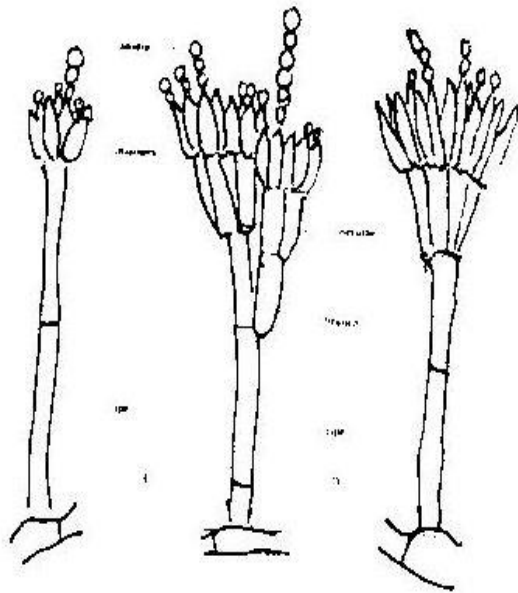
.Geotrichum



yeastlike, white

G. candidum: machinery mold.

Penicillium 青黴菌屬



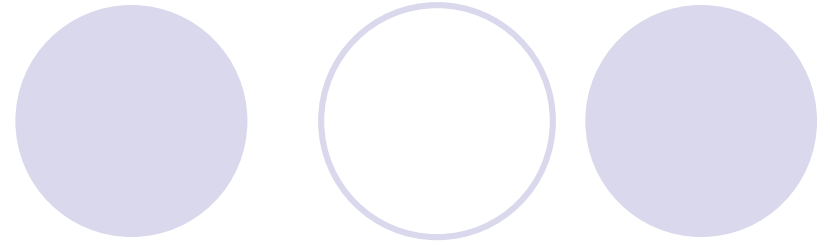
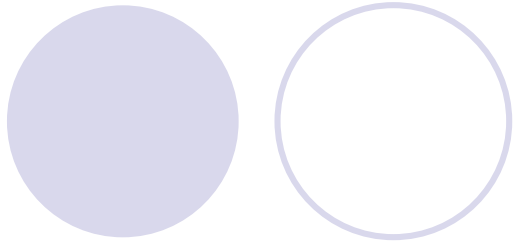
P.chrysogenum: produce gluconic acid,
protease, penicillin.

P.camemberti: Camembert cheese

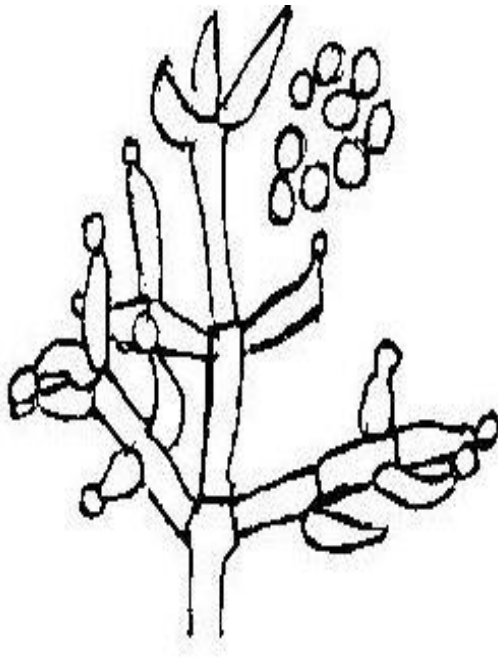
P.cyclopium: penicillic acid (mycotoxin)

P.viridicatum: citrinin ochratoxin

P.expansum: patulin (apple)

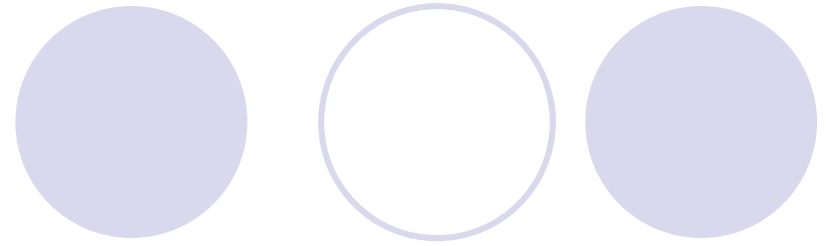
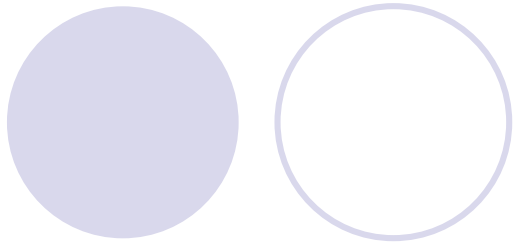


. Trichoderma



T. viride

T. roseum:cellulolytic



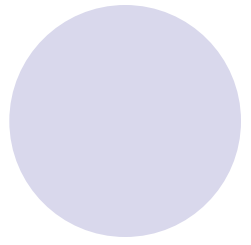
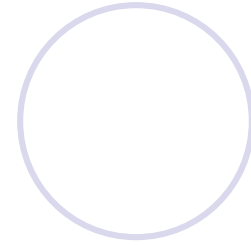
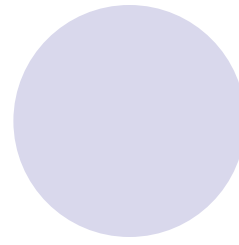
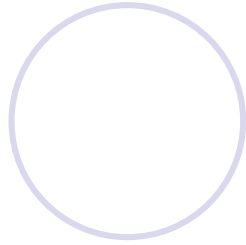
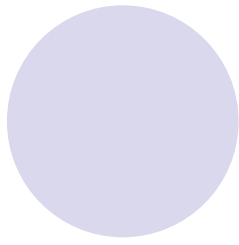
Yeasts

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. hanaseni: high salt tolerance. (18~21% salt)

film forming yeast in brine

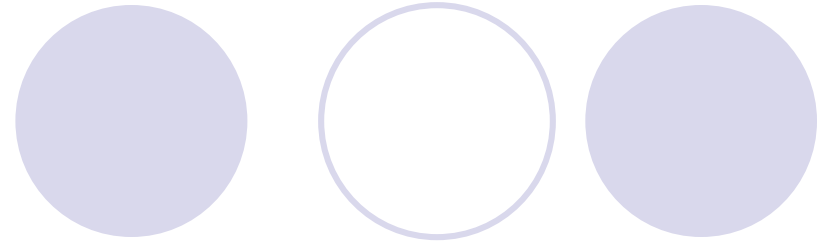
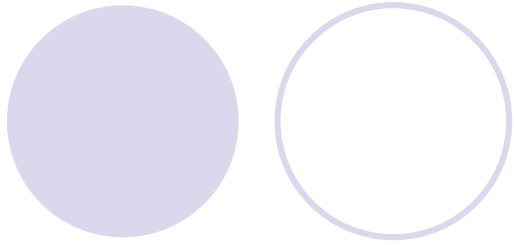
slime on salted meats

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

.Hanseniaspora

inositol & pantothenate: growth factor.

can be used to assay for these compounds.



.Hansenula

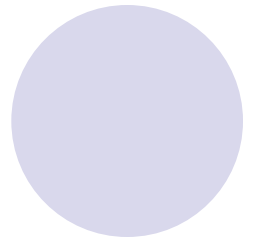
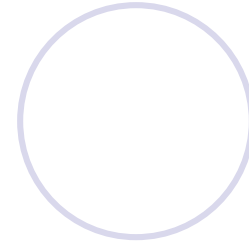
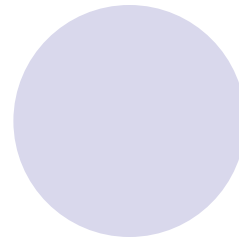
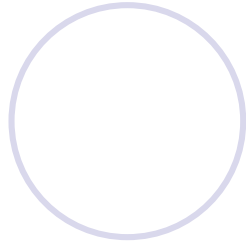
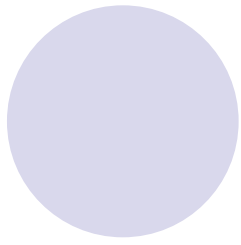
assimilate nitrate.

pseudomycelium or true mycelium may be formed.

.Kluyveromyces

can use lactose

whey→alcohol by *Kluyveromyces*



.Pichia

film forming yeast on liquid media or brine.
budding & from pseudomycelium.

.Saccharomyces

sugar fermentation, not use lactose & nitrate.

S. cerevisiae & *S. uvarum*

S. rouxii: osmophilic yeast, soy sauce.

S. bailii: xerotolerant

S. bisporus: xerophilic