



# Food Microbiology

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# *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, H<sub>2</sub>S, dimethyl sulfide)
- 11) seawater needed in media (see Bergey's Manual of Systemic Bacteriology Volume 1, 1984)



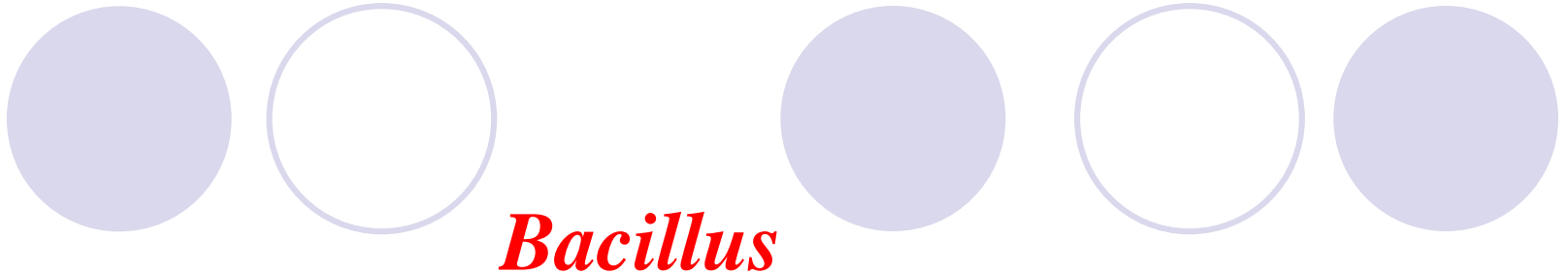
## *Acetobacter*

- 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*



- 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] <sup>a</sup> (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
● Grape (Concord)			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 CO<sub>2</sub> 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 CO<sub>2</sub>



## *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% O<sub>2</sub> and 10% CO<sub>2</sub>**
- 10) **food gastroenteritis from water**, raw milk, undercooked pork and poultry
- 11) complex, see current literature

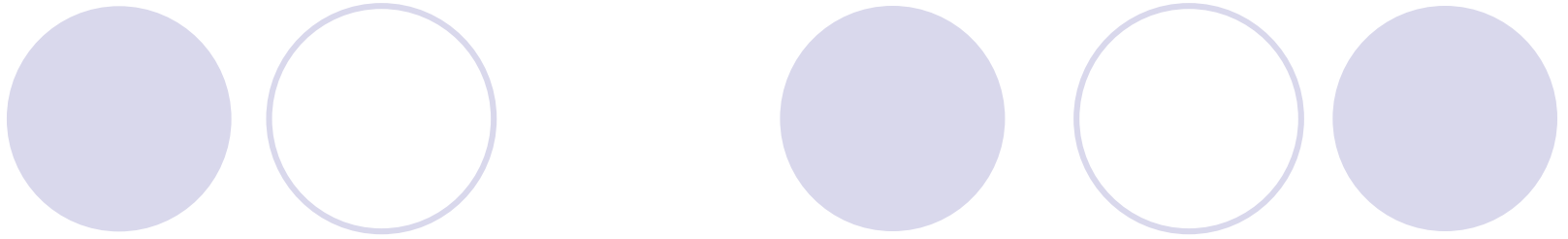


- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) rods
- 4) uses citrate as sole carbon source, motile with peritrichous flagella, grows on KCN, carbohydrate fermented to acid & gas (CO<sub>2</sub> + H<sub>2</sub>), IMVC (±+--+)
- 5) optimum 30 to 37°C
- 6) optimum around neutral pH
- 7) water, feces, urine,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



## *Clostridium*

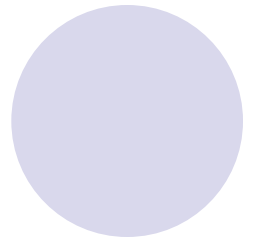
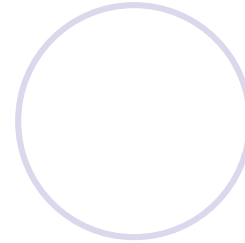
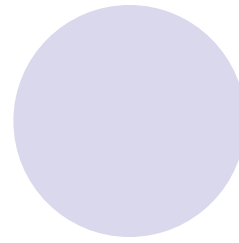
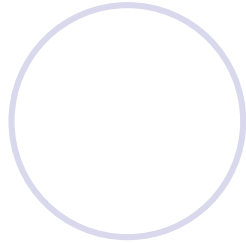
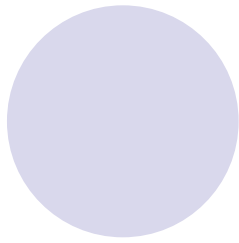
- 1) *Bacillaceae*
- 2) **Gram(+)** (especially in early stages)
- 3) rods – with oval spore that distends the bacilli
- 4) catalase(-), nonmotile or motile with peritrichous flagella, anaerobic, saccharolytic or proteolytic, **produce acid and gas**
- 5) 0 to 70°C, optimum depends on species
- 6) 3.0 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

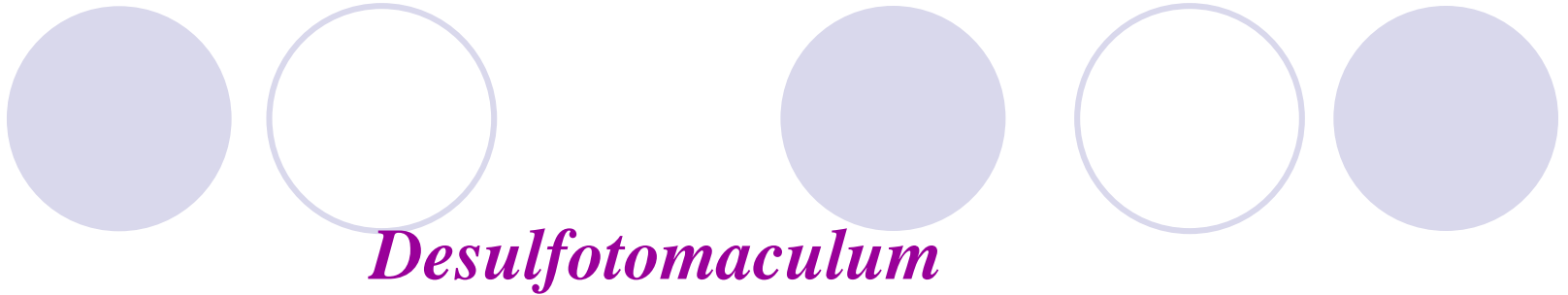
***C. botulinum*** – optimum temp. 30 to 40°C, putrefactive, produces potent **neurotoxin, food intoxication** mainly from home processed foods and usually is type A. Type E from fish, spores 120°C for 4 minutes to destroy, toxin Type A 80°C for 6 minutes to destroy





***C. perfringens*** – optimum temp. 45°C, nonmotile, require amino acids and growth factors, pH 5 to 8, H<sub>2</sub>S produced in most media, spores need minutes to 6h at 100°C for inactivation, **produced toxin** ( $\alpha$ -in US) in intestine from cooked meat and related foods causes food poisoning

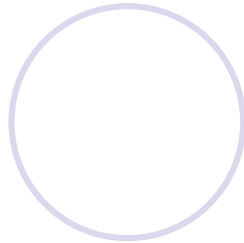
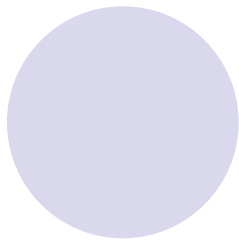
***C. thermosaccharolyticum*** – obligate thermophile with optimum at 55°C, **thermophilic anaerobe (TA)** causing **hard swell** (彈跳罐，膨罐的一種) in non-acid canned foods, coagulates milk, degrades sugar



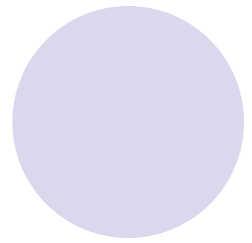
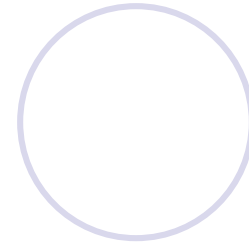
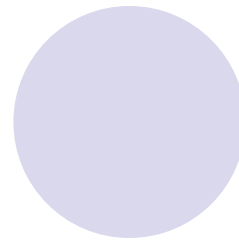
- 1) *Bacillaceae*
- 2) **Gram(+)**
- 3) straight or curved rods with rounded ends, single or sometimes in chains; **spores** are oval to round, terminal to subterminal, and cause swelling of cells
- 4) anaerobic, catalase (-), sulfate reduced to sulfide, respiratory metabolism, motile by peritrichous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



- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) short rods
- 4) catalase (+), oxidase (-), no H<sub>2</sub>S, 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°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



- 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



## *Klebsiella*

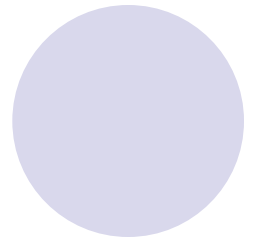
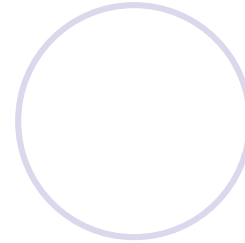
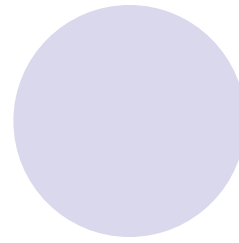
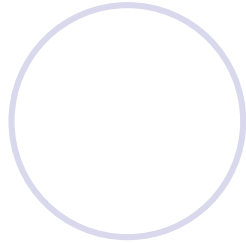
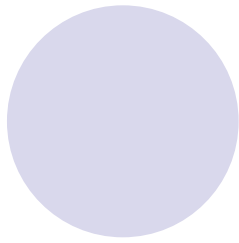
- 1) *Enterobacteriaceae*
- 2) Gram (-)
- 3) capsulated rods – single, pairs or chains
- 4) oxidase (-), catalase (+), acid & gas by 2,3 – butanediol fermentation, H<sub>2</sub>S not produced, nonmotile, IMVC (D,D,D,D), resistant to penicillin
- 5) optimum 35 to 37°C
- 6) optimum 7.2
- 7) respiratory 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. tricoles* – 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<sub>2</sub> and 5 to 10% CO<sub>2</sub>), 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, H<sub>2</sub>S(-), 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

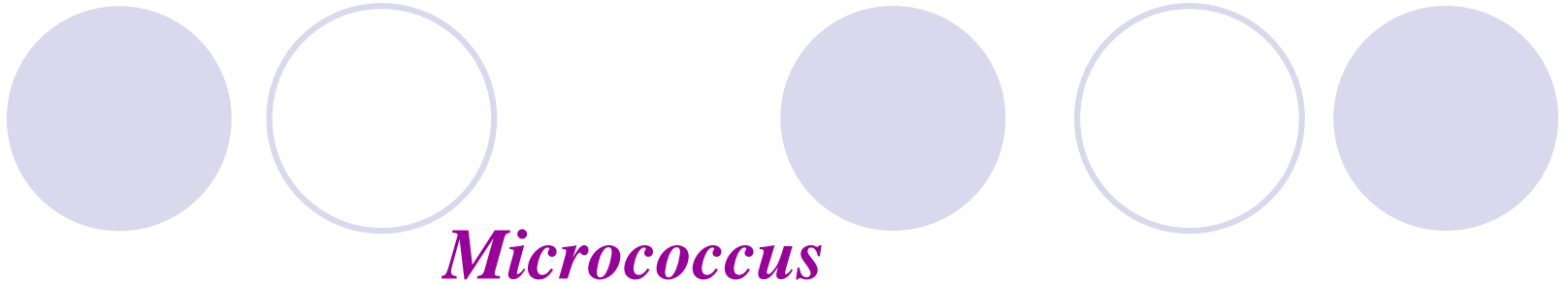


8) *L. monocytogenes*

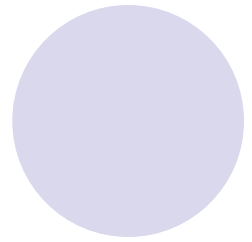
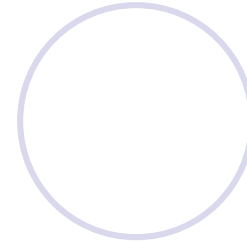
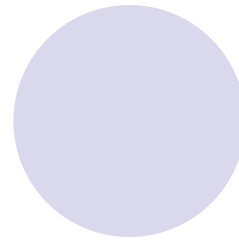
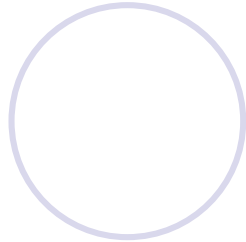
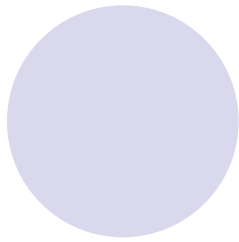
9) able to grow at refrigeration temperatures, produces gastroenteritis and leukocytosis and monocytosis (mild influenza-like illness to meningitis, bacteremia endocarditis, and central nervous system infection; many patients have other medical disorders or are on immunosuppressive drugs) with a mortality 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% CO<sub>2</sub>, 5% O<sub>2</sub> and 85% N<sub>2</sub> and 35°C

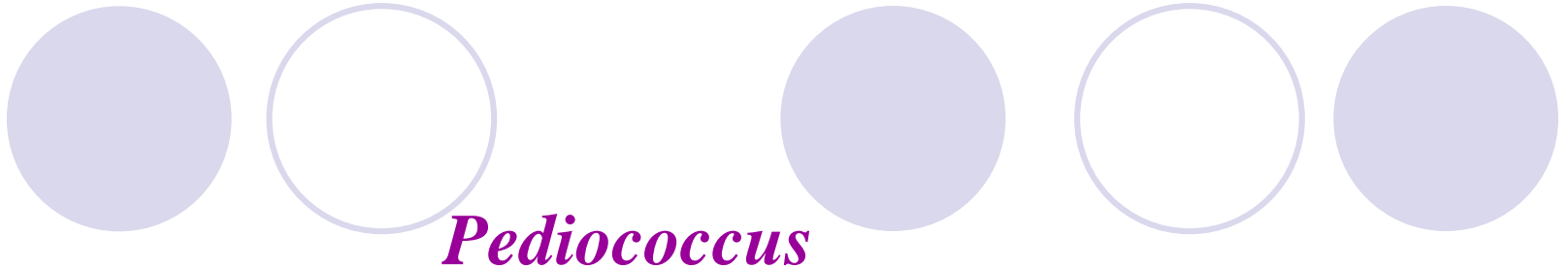


- 1) *Micrococcaceae*
- 2) **Gram (+)**
- 3) cocci-irregular clusters, single or pairs
- 4) catalase (+), tolerates 5-15% salt, water soluble pigment (yellow, orange & red), lysostaphin (-), nonmotile, strict aerobe
- 5) optimum = 25-30°C, range = 0 to 45°C
- 6) range = 5 to 8.5
- 7) fresh & salt water,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



- 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<sub>2</sub> for 7 to 10 days at 30°C





## *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**

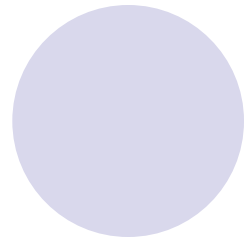
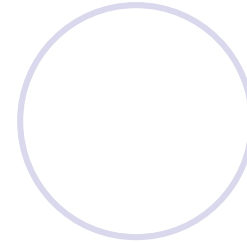
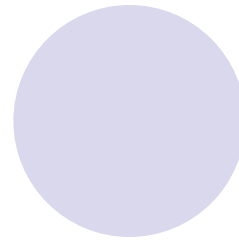
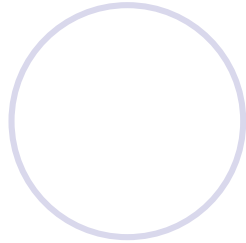
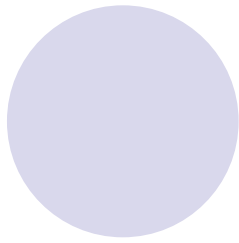
10) **spoilage of meats, poultry seafood, eggs, dairy products**

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 H<sub>2</sub>S, 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



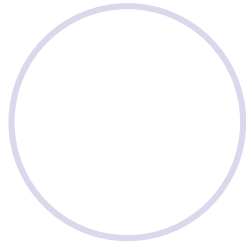
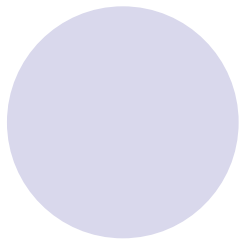
8) ***S. typhi*** – typhoid fever

***S. typhimurium*** – most often in food poisoning outbreaks

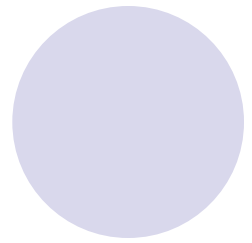
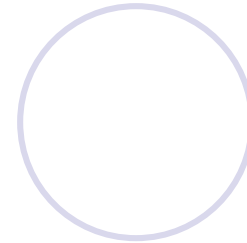
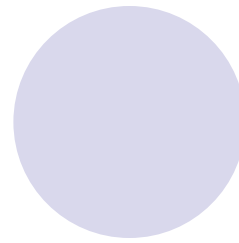
9) **causes food infection** due to ingestion of large number of cells, classified by serology (O, K, and H antigens)

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<sub>2</sub>S 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



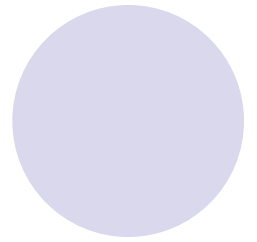
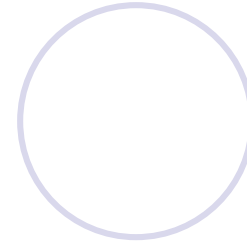
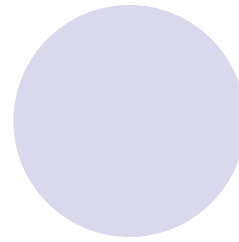
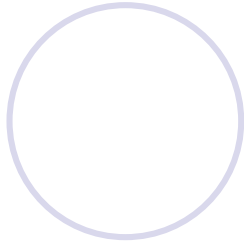
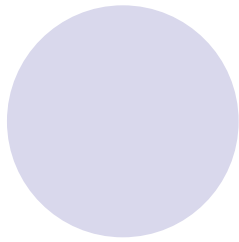
- 10) cause dysentery when transmitted by water and food
- 11) use gram-negative broth followed by selective agars  
(low=MacConkey or Tergitol 7 Agar;  
intermediate=Xylose-Lactose-Desoxycholate (XLD);  
high=Salmonella-Shigella Agar or Hektoen Enteric Agar);  
confirm by biochemical tests and serology



## *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>Enterococcc</u> <u>us</u>	<u>Lactococc</u> <u>us</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, thermoduric, grows 5 to 50°C, 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°C

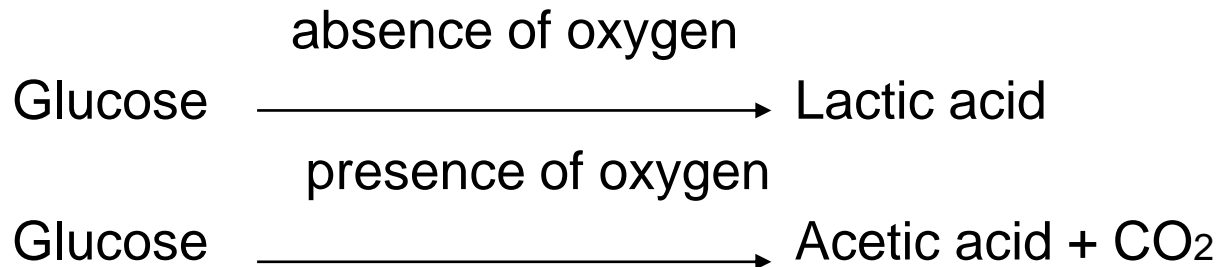
11) use selective media for lactics or acid-producers (Lactic Agar, Trypticase Soy Agar with Bromcresol purple, etc.)

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

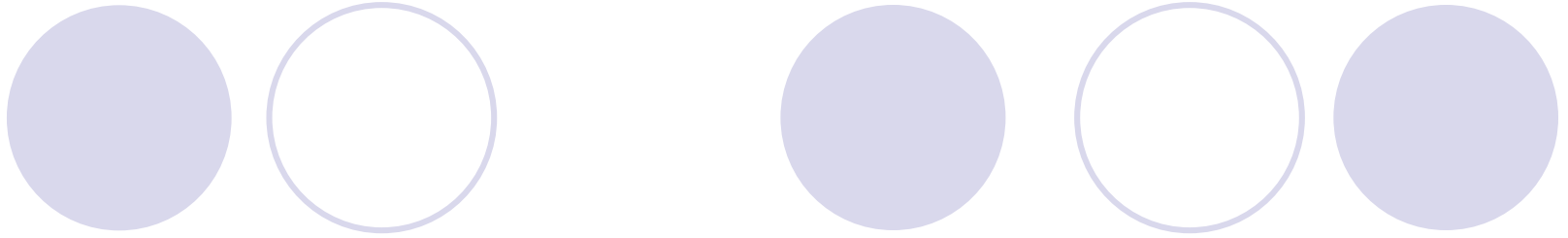


## *Staphylococcus*

- 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



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

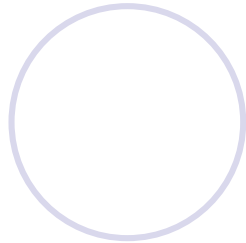
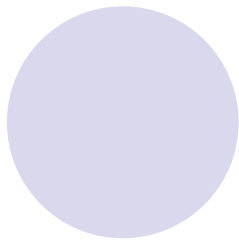
produces coagulase, hemolysins, lipases,

deoxyribonucleases, catalase, protease, enterotoxins

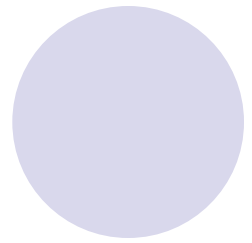
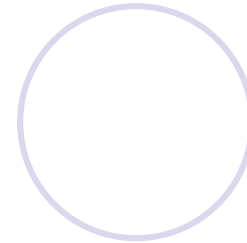
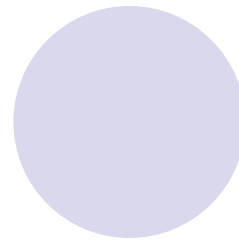
10) grow in wide variety of foods

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 H<sub>2</sub>S 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)

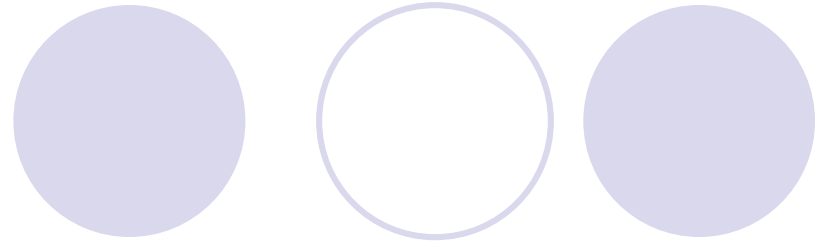
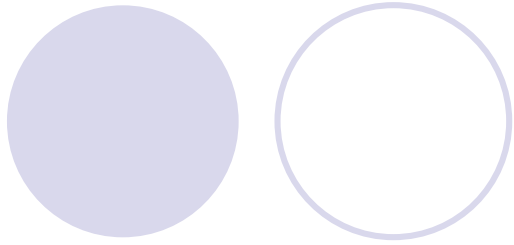
.dichloran: inhibit spreading

.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**

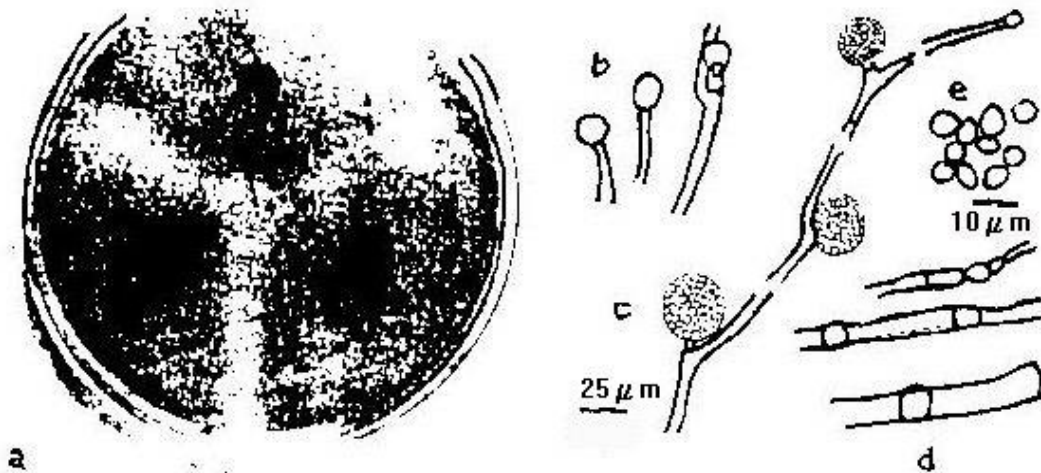
- Spoilage
- Health hazards (mycotoxins)
- fermentation

## (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

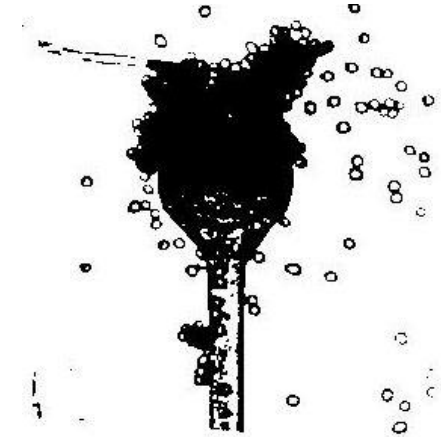
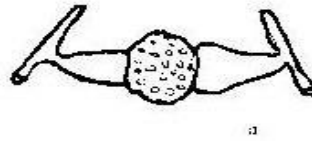
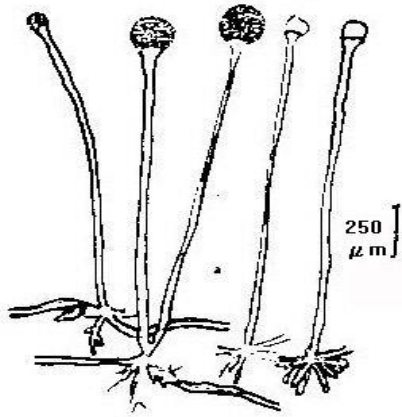
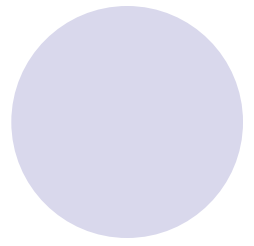
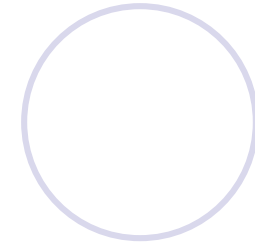
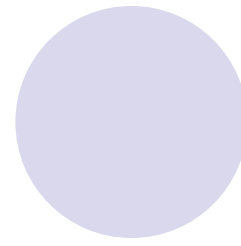
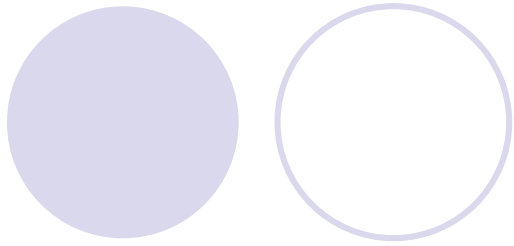




***Rhizopus*** -類似 *Mucor*，有Rhizoid，亦為糖化菌一種

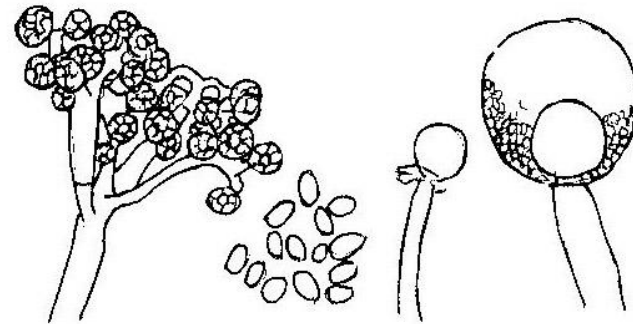
***R.stolonifer***: bread mold

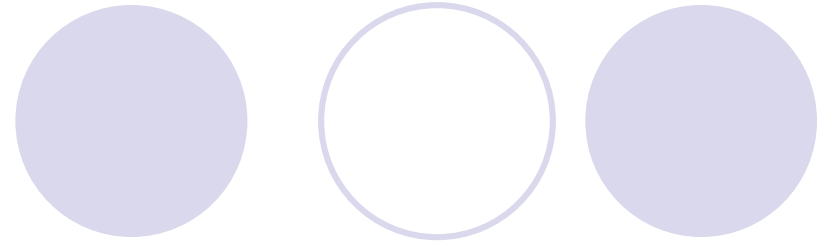
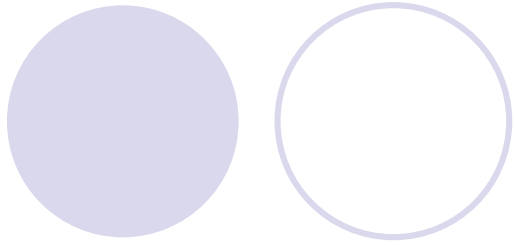
***R.oligosporus***: Tempeh



***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 O<sub>2</sub> → produce pectic enzyme → soft texture of  
canned

& fruits → spoilage

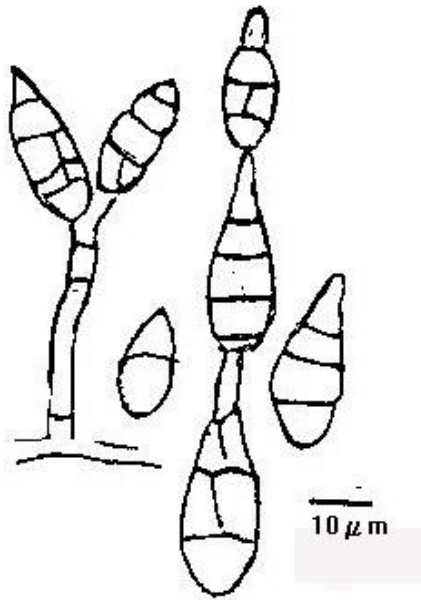
*B. fulva* : heat resistant spore

(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



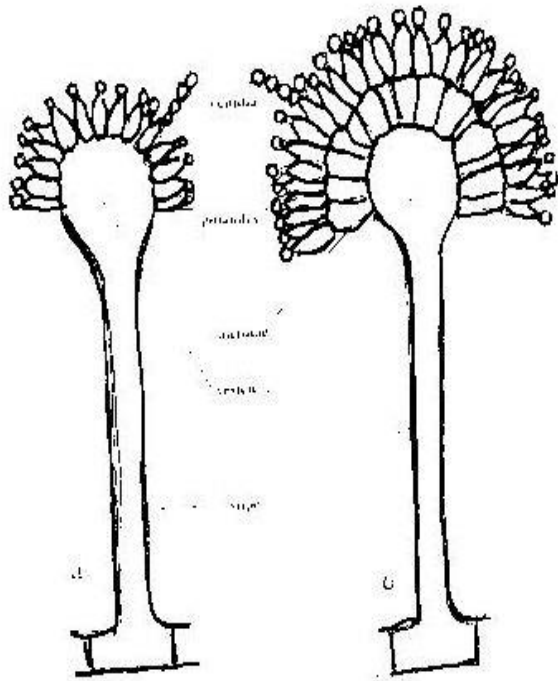
黑色孢子

plant pathogens

spoilage of tomato in the field

*A.alternate* produce mycotoxins (alternarin)

# *Aspergillus* 麴黴



*A. niger*: black conidia, citric acid.

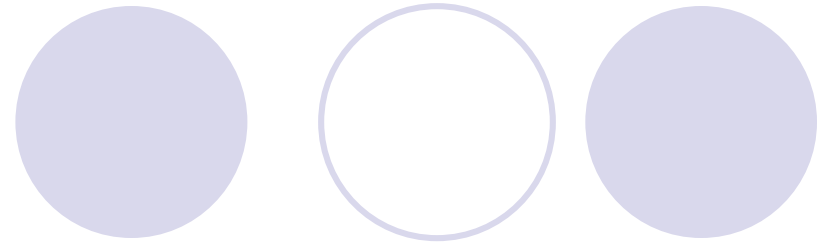
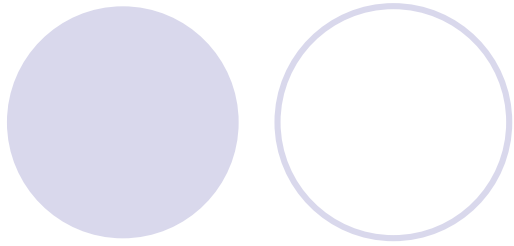
*A. flavus* & *A. parasiticus*: yellow-green aflatoxin

*A. candidus*: white conidia

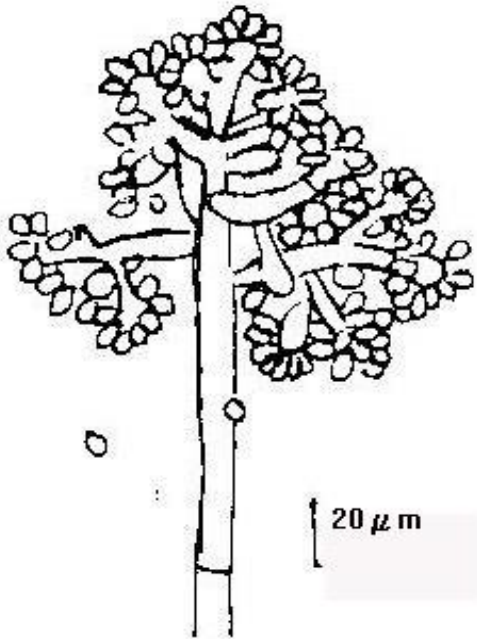
*A. ochraceus*: yellow-brown conidia, dry food ochratoxin.

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





*Botrytis* 蠶絲菌屬



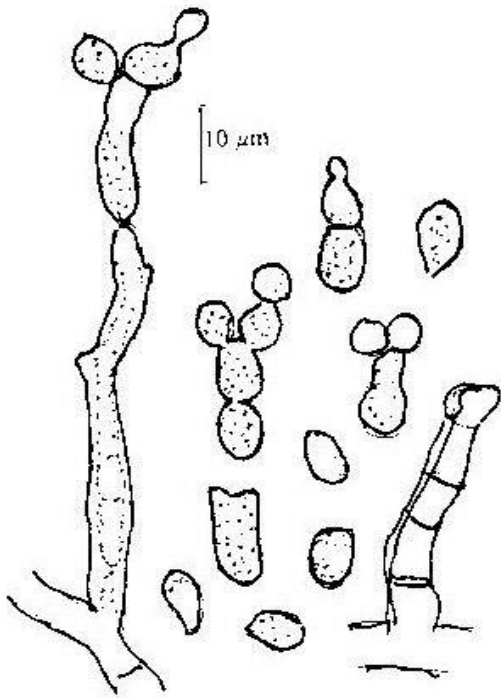
*B. cinerea*

如樹枝狀分支

灰色

fruit & vegetable spoilages

*.Cladosporium* 分枝黴菌

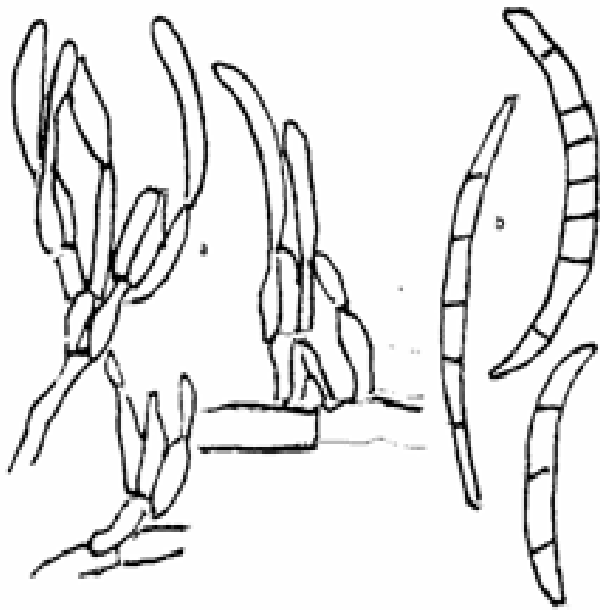


分隔，由之產生厚膜孢子

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

*C. cladosporioides*: grains, flour, vegetable

*Fusarium* 镰刀菌属



plant pathogens

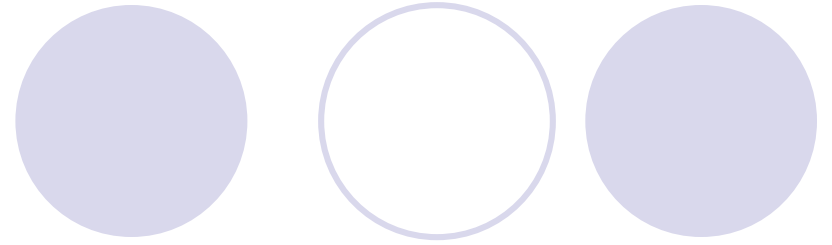
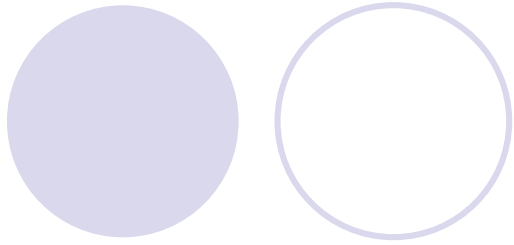
*F.moniliforme*: gibberellic acid

一種植物生長激素

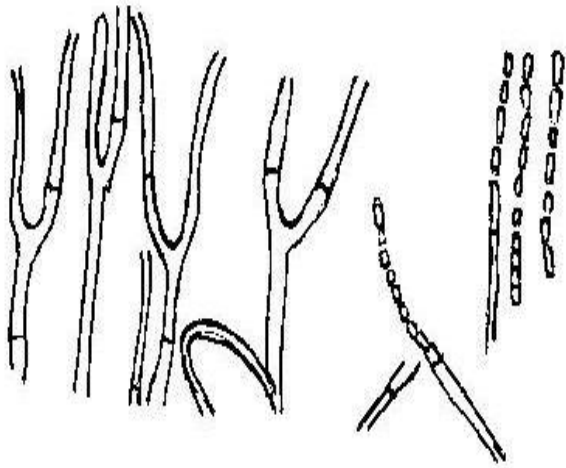
*F.oxysporium*

*F.roseum* Zearalenone

*F.tricinctum* (mycotoxin)



## *.Geotrichum*

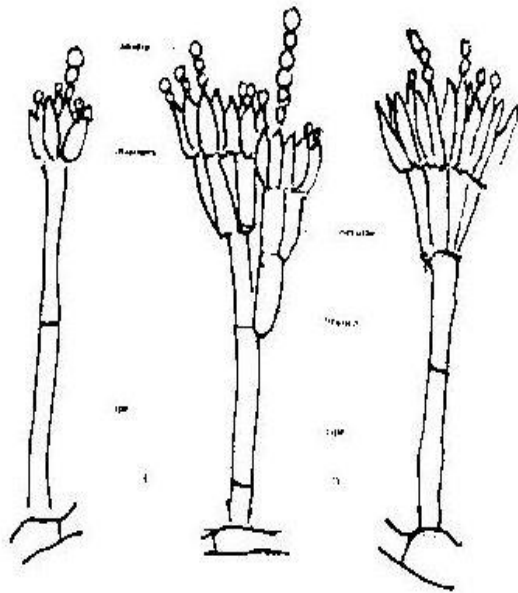


yeastlike, white

***G. candidum***: machinery mold.



## *Penicillium* 青黴菌屬



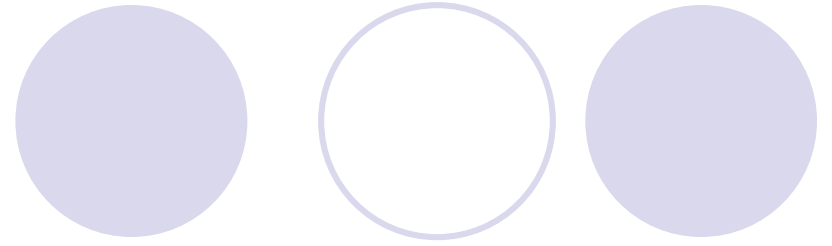
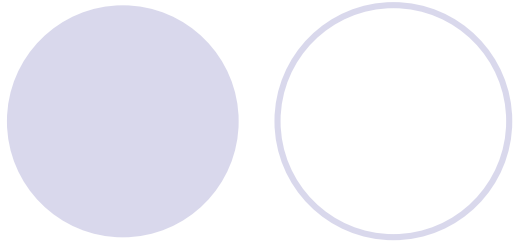
*P.chrysogenum*: produce gluconic acid,  
protease, penicillin.

*P.camemberti*: Camembert cheese

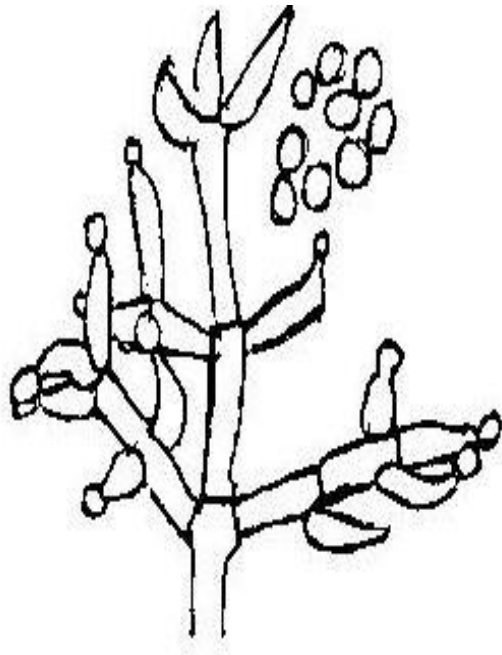
*P.cyclopium*: penicillic acid (mycotoxin)

*P.viridicatum*: citrinin ochratoxin

*P.expansum*: patulin (apple)



## *. Trichoderma*



*T. viride*

*T. roseum*:cellulolytic



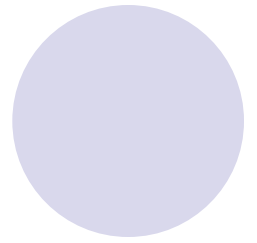
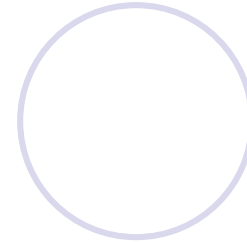
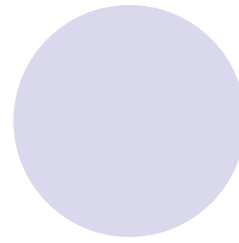
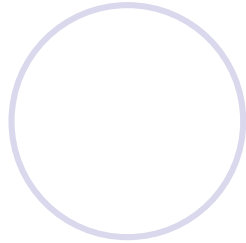
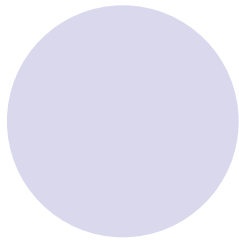
## Yeasts

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

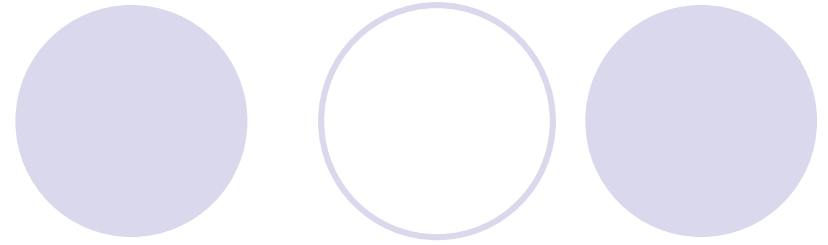
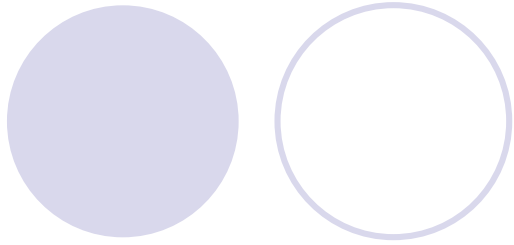
spoilage of orange juice, yogurt, cheese, wine, . . .

## *.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 & form pseudomycelium.

## *.Saccharomyces*

sugar fermentation, not use lactose & nitrate.

*S. cerevisiae* & *S. uvarum*

*S. rouxii*: osmophilic yeast, soy sauce.

*S. bailii*: xerotolerant

*S. bisporus*: xerophilic