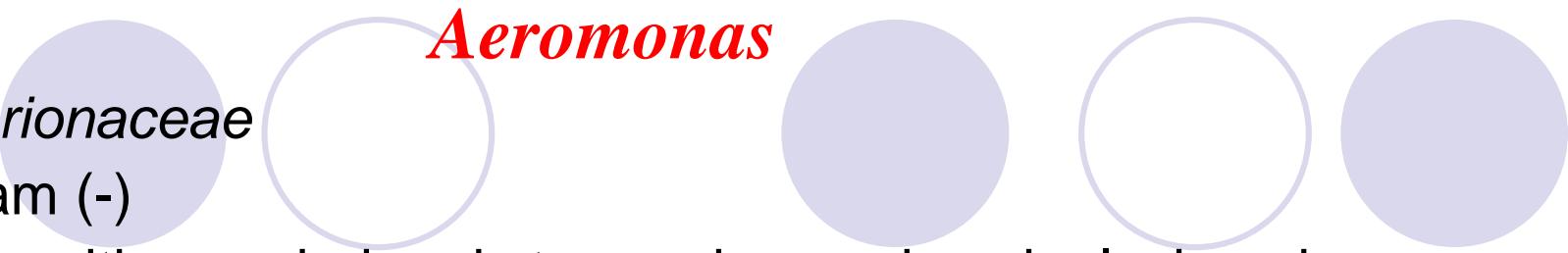


# Food Microbiology

Guo-Jane Tsai, Ph.D.



## 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)



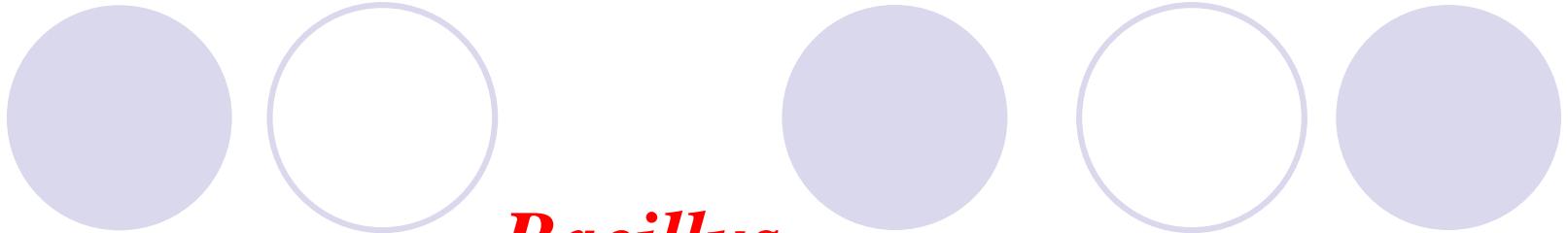
## *Acetobacter*

- 1) *Acetobactereaceae*
- 2) Gram(-)
- 3) straight or curve ellipsoidal to rod shaped; single, pairs or chains
- 4) respiratory and never fermentative, **strict aerobes**, motile by peritrichous flagella or nonmotile, oxidize ethanol to acetic acid, catalase (+), oxidase (-)
- 5) 5 to 42°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 ropy and sour beer due to acetification, rot in apples and pears
- 11) medium with 0.5% yeast extract, 1.5% ethanol, and 2.5% agar



## *Arthrobacter*

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

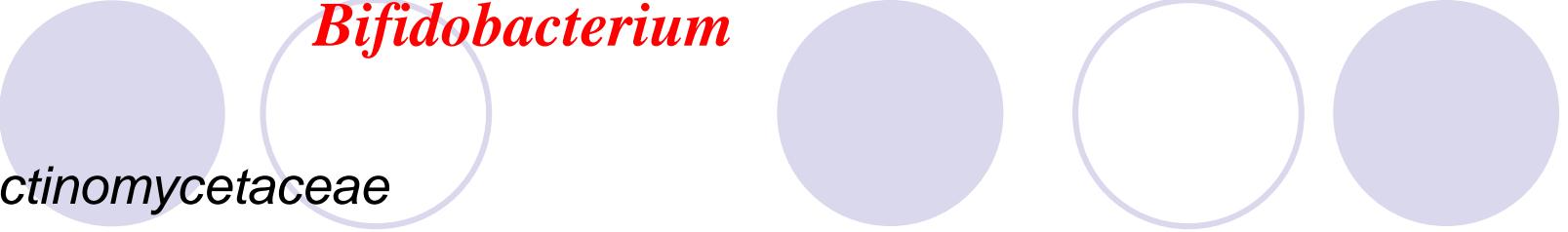
*B. coagulans* – temp. 15 to 60°C, pH 4.0 to 6.0 optimum, spores (121°C for 0.7 minutes to destroy), “**flat sour**” in canned foods (平酸罐), used to produce lactic acid commercially

# *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 [ $\pm$ SD]a (min)
Blackcurrant (Light)	26.10	2.50	91	3.84 [ $\pm$ 0.49]
Blackcurrant	58.50	2.50	91	24.10 [ $\pm$ 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 [ $\pm$ 1.50]
			85	25.00 [ $\pm$ 0.10]
			90	11.66 [ $\pm$ 1.80]
			95	8.33 [ $\pm$ 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) saccharolytic, 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>

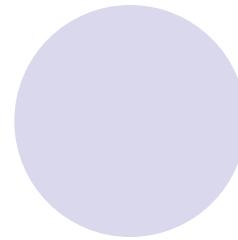
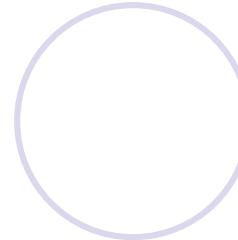
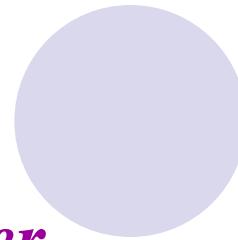
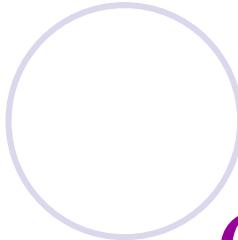
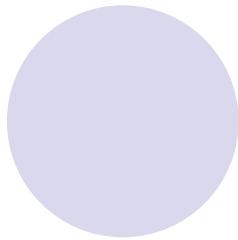


## *Brevibacterium*

- 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*

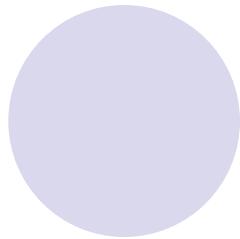
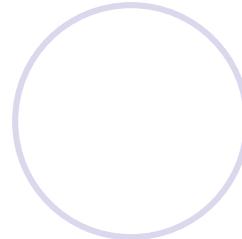
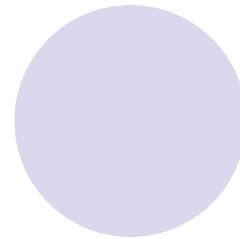
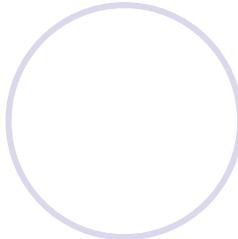
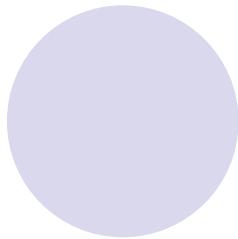
# *Campylobacter*

- 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 form amino acids or TCA cycle intermediates and not carbohydrates
- 5) growth at 25°C, but usually not 42°C, optimum = 37°C
- 6) optimum = pH 7.0
- 7) infected animals, intestinal tract, water
- 8) *Campylobacter fetus* subsp. *jejuni*  
*Campylobacter fetus* subst. *intestinalis*
- 9) motile by corkscrew action, growth best in 5% O<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



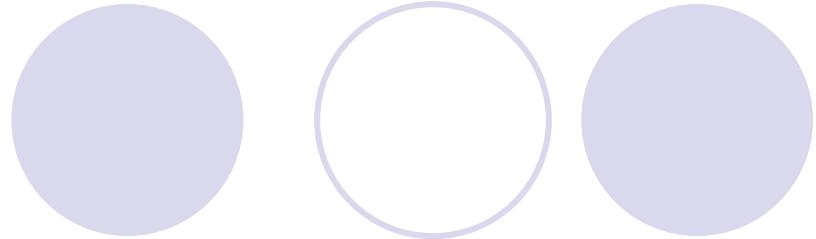
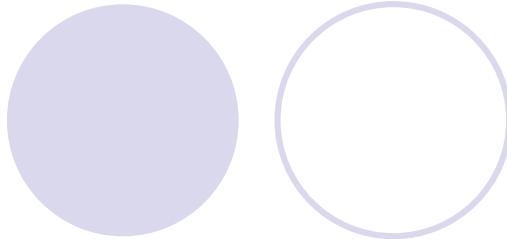
## *Citrobacter*

- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) rods
- 4) uses citrate as sole carbon source, motile with peritrichous flagella, grows on KCN, carbohydrate fermented to acid & gas ( $\text{CO}_2 + \text{H}_2$ ), 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*



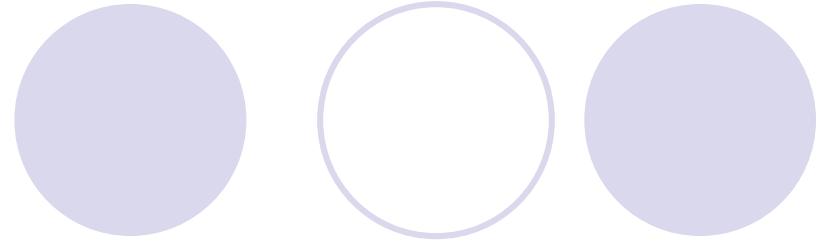
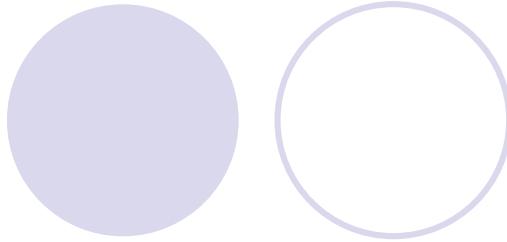
## *Clostridium*

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



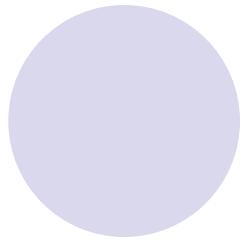
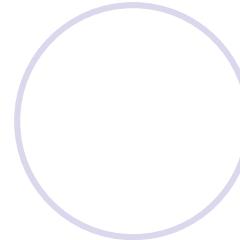
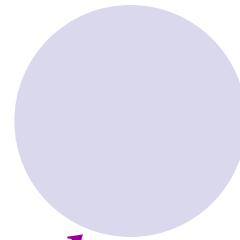
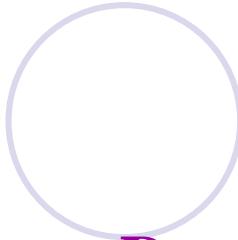
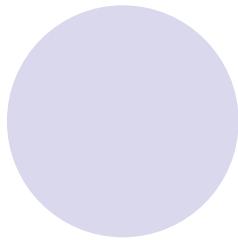
***C. sporogenes*** – optimum temp. 30 to 40°C, digests milk, putrefactive anaerobe that spoils acid and low acid foods, **【PA 3679】** is a tested organism for heat processing canned foods, causes explosion in chocolates

***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



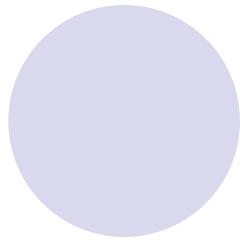
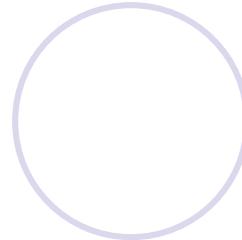
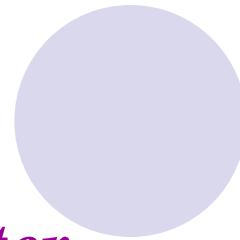
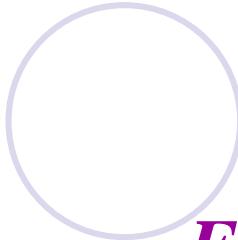
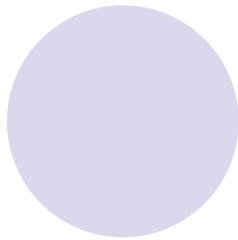
*C. perfringens* – optimum temp. 45°C, nonmotile, require amino acids and growth factors, pH 5 to 8, H<sub>2</sub>S produced in most media, spores need minutes to 6h at 100°C for inactivation, **produced toxin** ( $\alpha$ -in US) in intestine from cooked meat and related foods causes food poisoning

*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



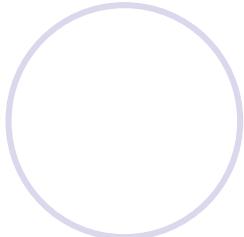
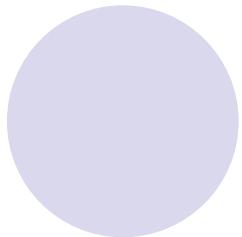
## *Desulfotomaculum*

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

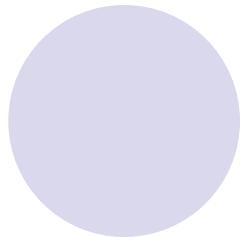
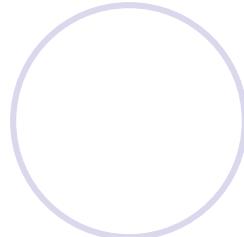
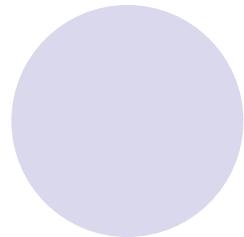


## *Enterobacter*

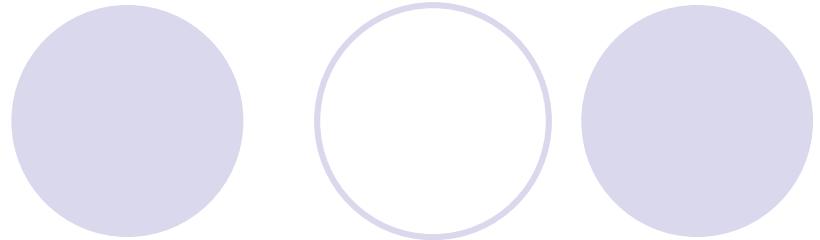
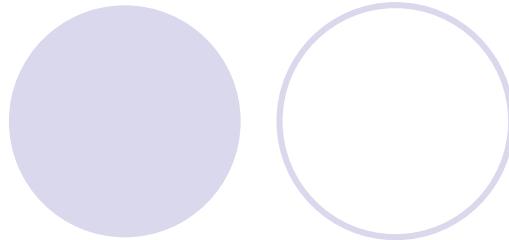
- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) short rods
- 4) catalase (+), oxidase (-), no H<sub>2</sub>S, IMVC (---+), acid & gas by 2,3 butanediol fermentation, motile by peritrichous flagella, citrate & acetate used as sole carbon
- 5) optimum 30 to 37°C
- 6) 4.5 to 8.5
- 7) plants, soil, water & sometimes 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*

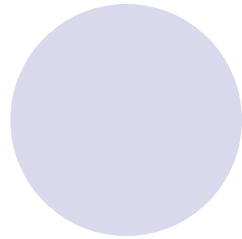
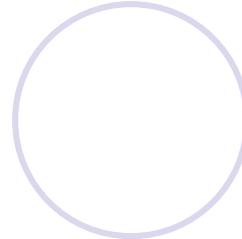
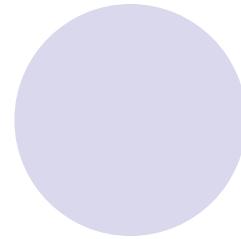
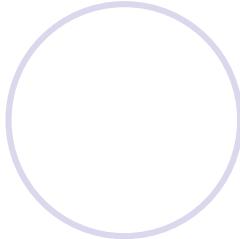
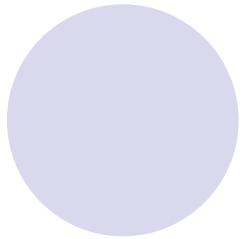


- 1) *Enterobacteriaceae*
- 2) Gram(-)
- 3) single straight rods
- 4) catalase (+), oxidase (-), acid but gas weak or absent, facultative anaerobes, motile by peritrichous flagella, **degrade pectins**, rarely produce urease or lipases, pigment yellow to red
- 5) optimum 27-30°C, range 1 to 40°C
- 6)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



## *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



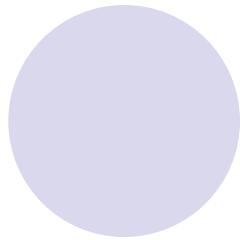
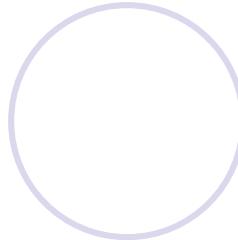
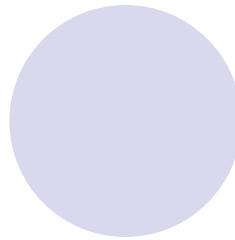
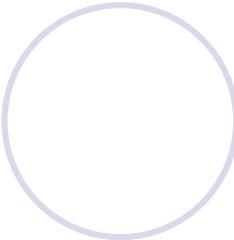
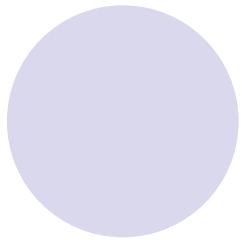
8) *E. coli*

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

9) used as fecal indicator for water foods

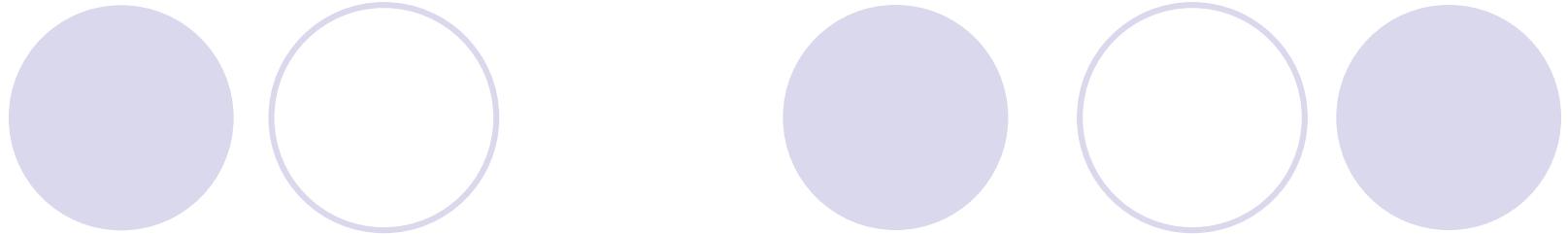
10) spoils meat, poultry, fish, eggs, dairy products; EEC causes diarrhea food poisoning especially in infants and travelers; ETEC causes traveler's diarrhea; *E. coli* O157:H7 causes hemorrhagic colitis

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



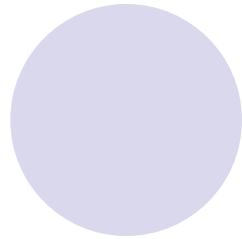
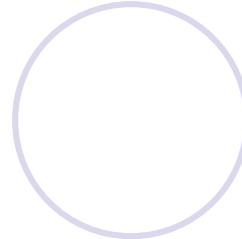
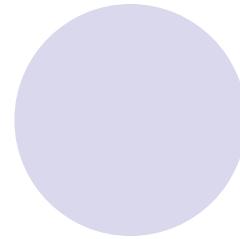
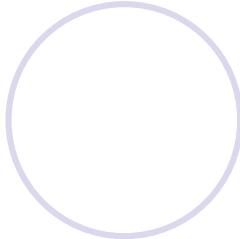
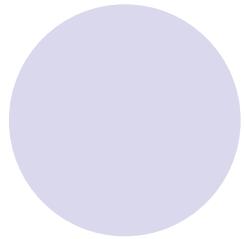
## *Klebsiella*

- 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)

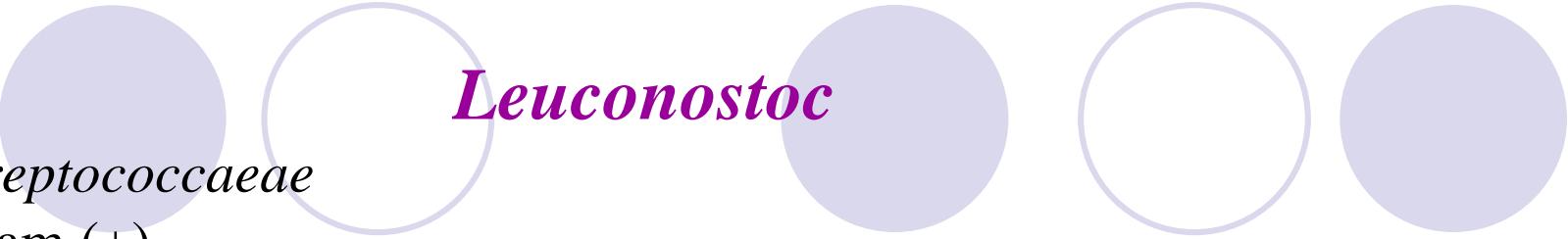
*\*L. viridescens* – greening of meat

*\*L. hilgardii* – deterioration of wine

*\*L. tricodis* – 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. lactis*** – 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*

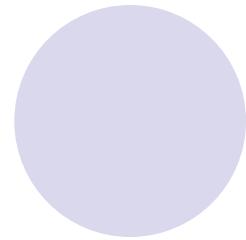
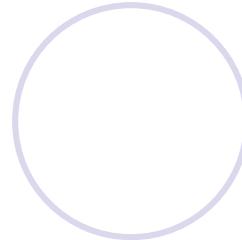
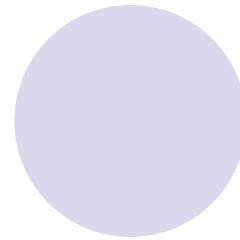
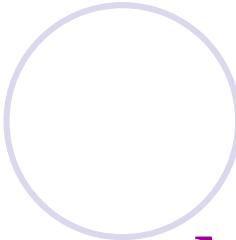
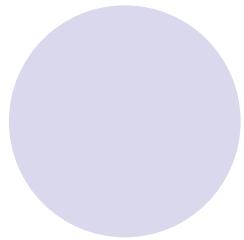
- 1) Genera of Uncertain Affiliation
- 2) **Gram (+)**; may strain Gram (-) if cells are old
- 3) coccoid rods in chains of 3 to 5 cells or in filamentous forms; diphteroid palisade layers can be seen when stained
- 4) **aerobic to microaerophilic** (reduced O<sub>2</sub> and 5 to 10% CO<sub>2</sub>), 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 moncytosis (mild influenza-like illness to meningitis, bacteremia endocarditis, and central nervous system infection; many patients have other medical disorders or are on immunosuppressive drugs) with a mortality rate of around 50%

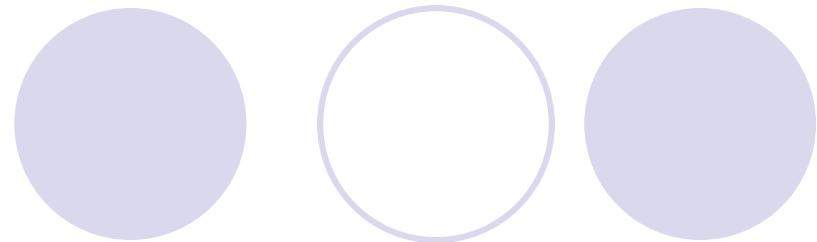
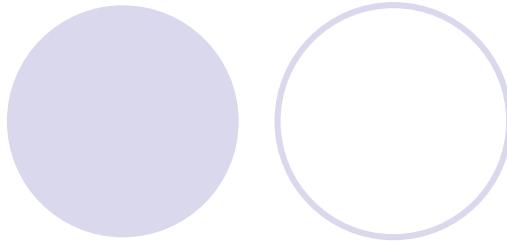
10) microorganism transported through milk or infected meat (rare)

11) isolate on sheep's blood agar, McBride's Listeria agar using atmospheres of 10% CO<sub>2</sub>, 5% O<sub>2</sub> and 85% N<sub>2</sub> and 35°C



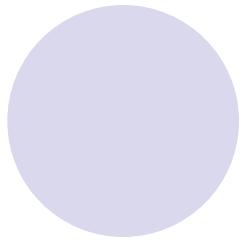
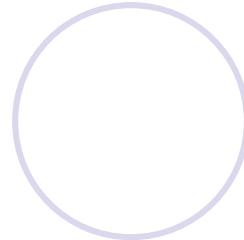
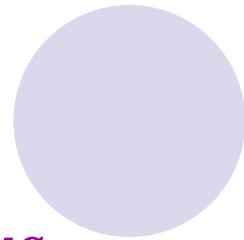
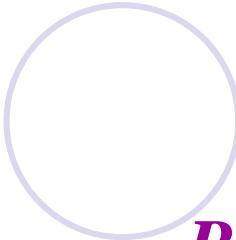
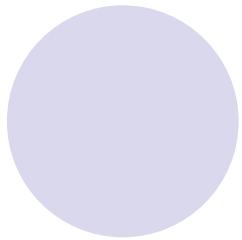
## *Micrococcus*

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



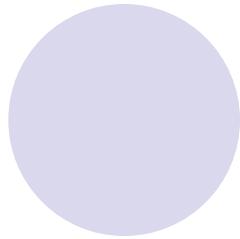
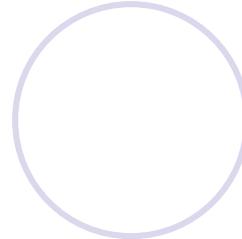
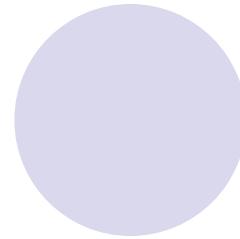
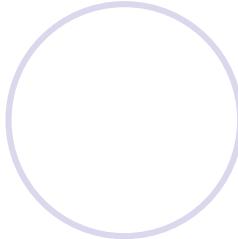
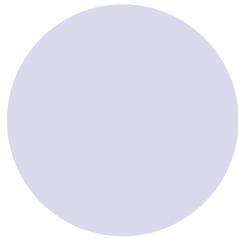
9) selective advantage:

- (a) **high salt foods**
- (b) use nitrate ion in place of oxygen – cured meats
- (c) **survive heating – milk pasteurization,**
- (d) more resistant to dehydration & radiation
- (e) sensitive to acid – inhibited at pH 5
- (f) **grow at refrigeration temperatures**
- (g) produce lipolytic & proteolytic enzymes, reduce nitrate to nitrite, and oxidize organic substrates
- (h) discolor food (yellow, pink) Note: Rarely primary source of spoilage since unable to grow rapidly & compete with other microorganisms – can be problems in above 8 cases if conditions are optimum.



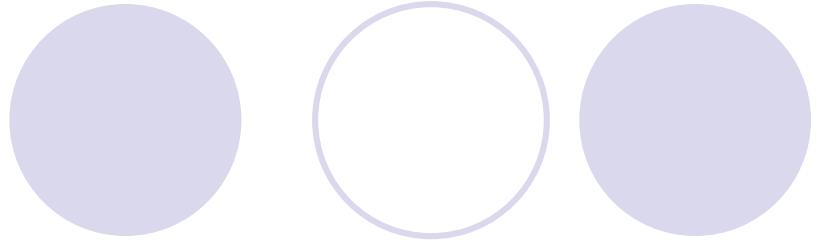
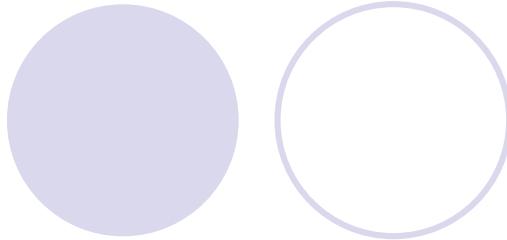
## *Pediococcus*

- 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*



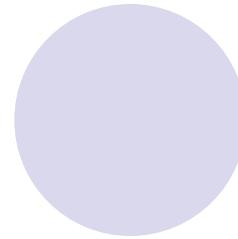
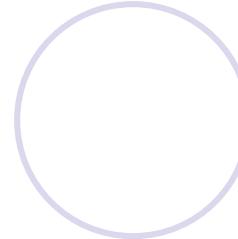
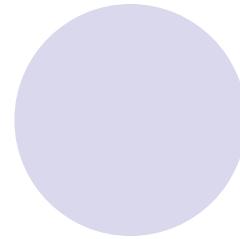
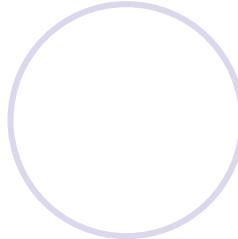
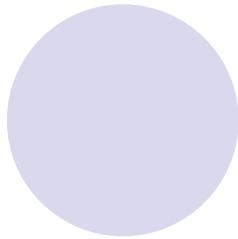
## *Propionibacterium*

- 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. freudenreichii* 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

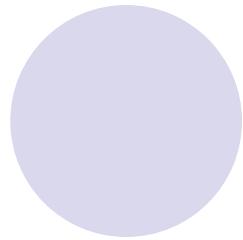
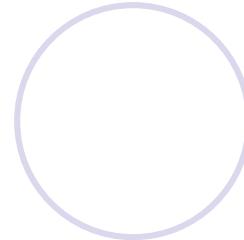
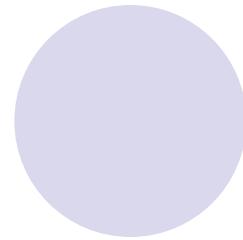
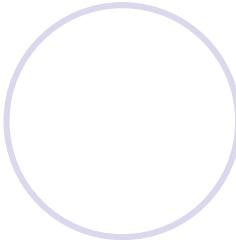
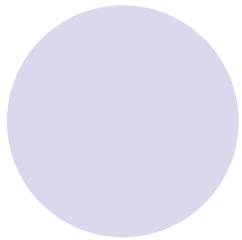


8) ***P. fluorescens*** – fluorescent pigment  
***P. aeruginosa*** – of clinical importance  
considerable regrouping of the gram negative rods has changed many of the names that appear in literature

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

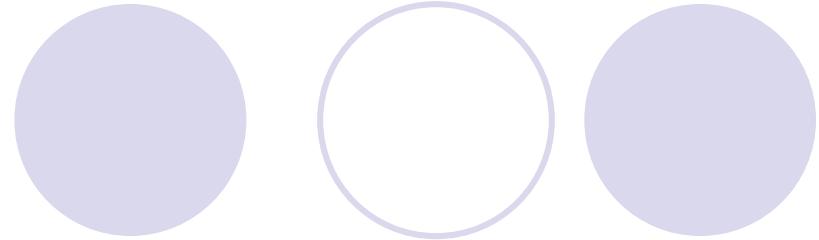
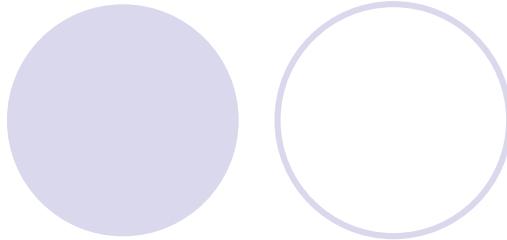
10) spoilage of meats, poultry, seafood, eggs, dairy products

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

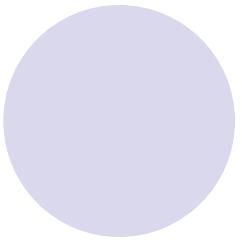
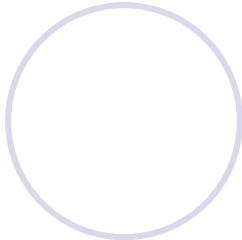
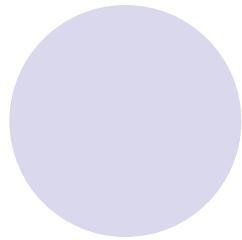
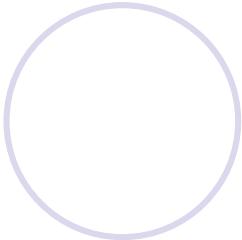
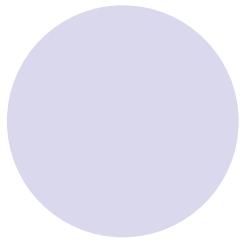


## *Salmonella*

- 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  $\text{H}_2\text{S}$ , 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

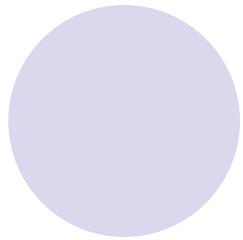
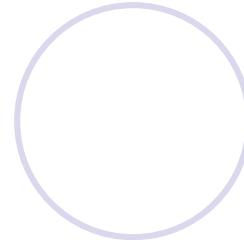
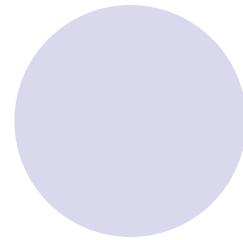
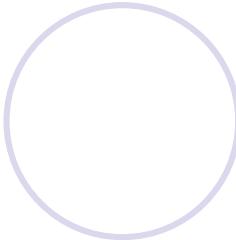
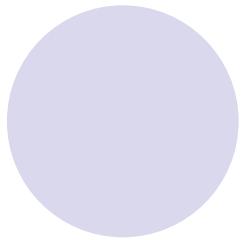


- 8) ***S. typhi* – typhoid fever**  
***S. typhimurium* – most often in food poisoning outbreaks**
- 9) **causes food infection** due to ingestion of large number of cells, classified by serology (O, K, and H antigens)
- 10) all species can cause food poisoning; spoils meat, poultry & eggs in mesophilic 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)



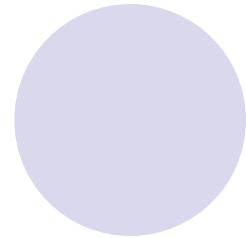
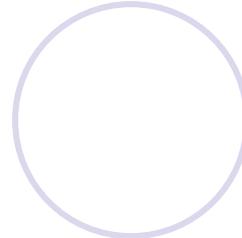
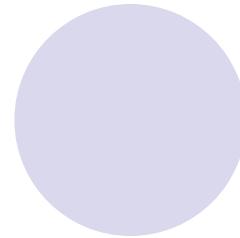
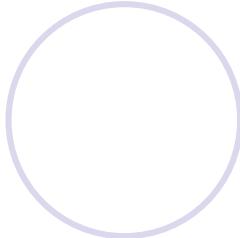
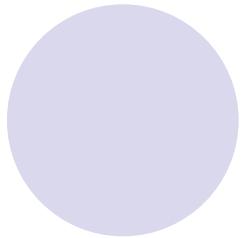
## *Serratia*

- 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*



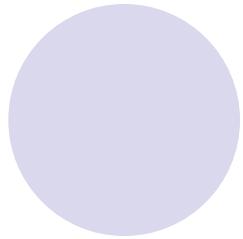
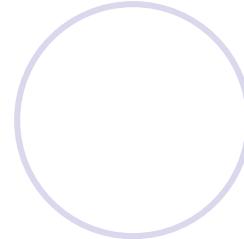
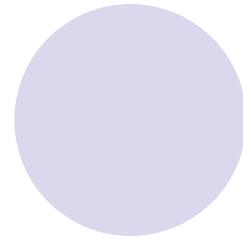
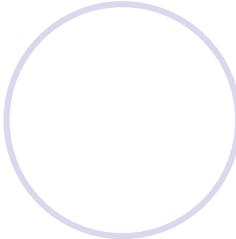
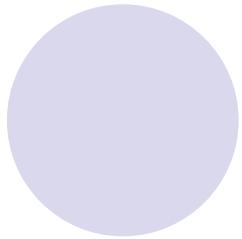
## *Shigella*

- 1) *Enterobacteriaceae*
- 2) Gram (-)
- 3) short rods
- 4) acid but not gas from carbohydrates, oxidase (-), catalase (±), 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>Enterococc us</u>	<u>Lactococc us</u>
10°C	-	-	+	+
45°C	-	+	+	-
pH 9.6	-	-	+	-
6.5 % NaCl	-	-	+	-
	<b><i>S. agalactiae</i></b>	<b><i>S. thermophilus</i></b>	<b><i>S. faecium</i></b>	<b><i>S. lactis</i></b>
	<b><i>S. pyogenes</i></b>		<b><i>S. faecalis</i></b>	<b><i>S. cremoris</i></b>

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

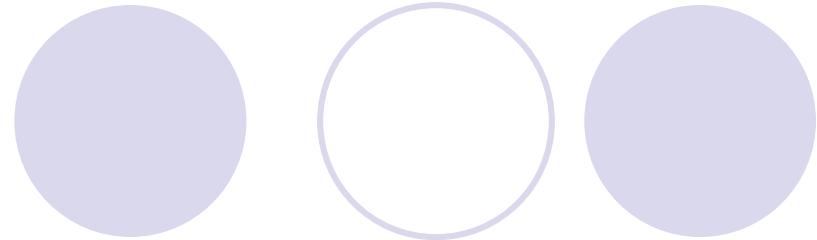
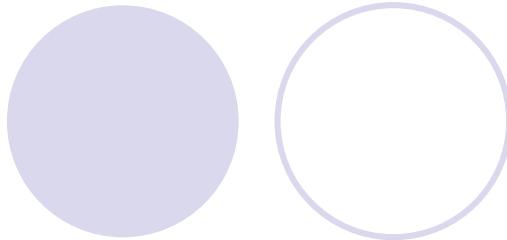
***S. faecium*** – common in plants, thermoduric

***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

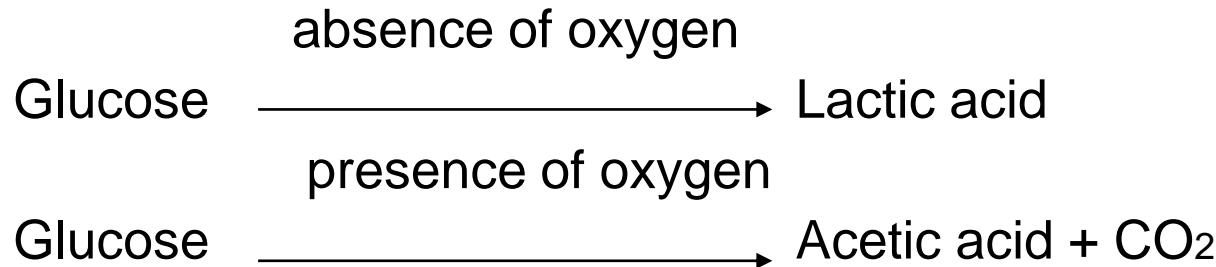
11) use selective media for lactics or acid-producers (Lactic Agar, Trypticase Soy Agar with Bromcresol purple, etc.)

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

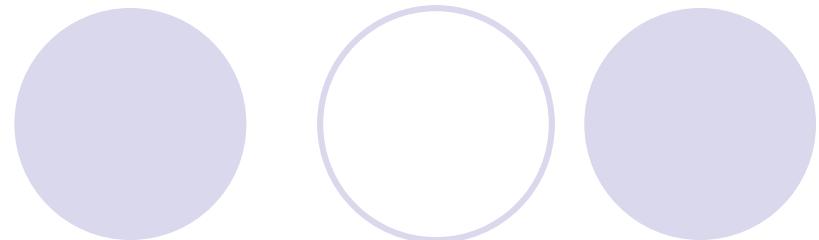
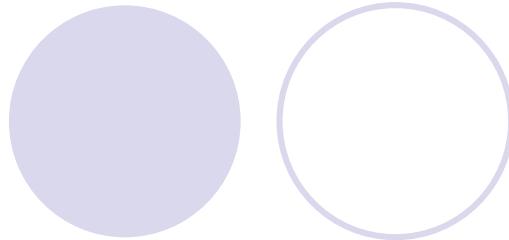


## *Staphylococcus*

- 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



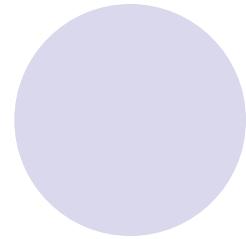
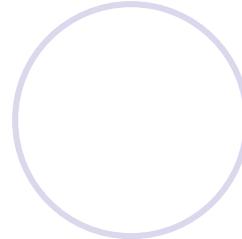
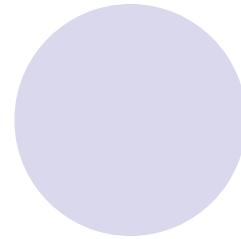
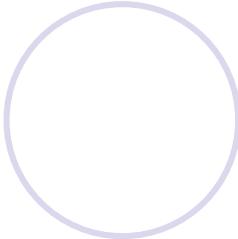
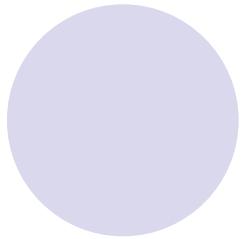
Grow in 15% NaCl or 40% bile & tolerate sodium azide, tellurite, mercuric chloride



- 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>	<u>Mannitol-Acid Anaerobically</u>	<u><math>\alpha</math>-toxin</u>
<i>S. aureus</i>	+	+	+
<i>S. epidermidis</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

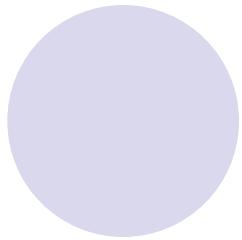
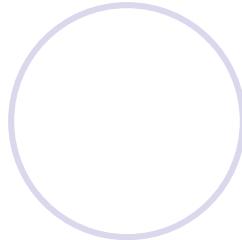
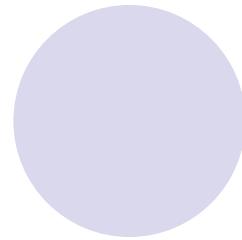
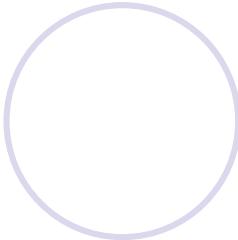
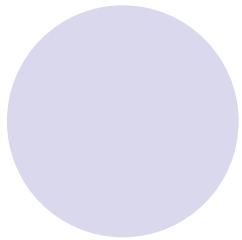
produces coagulase, hemolysins, lipases,

deoxyribonucleases, catalase, protease, enterotoxins

10) grow in wide variety of foods

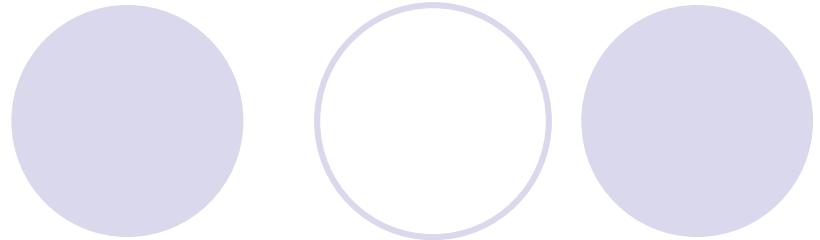
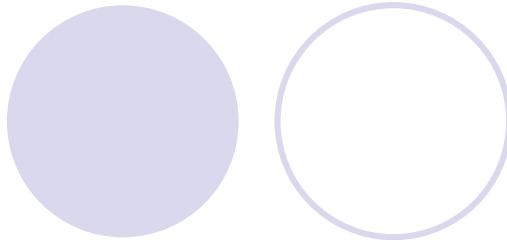
pathogenic – disease in all parts of body

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

(1) **Plating method:**

(a) Acidified medium (pH3.5)

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

.dichloran: inhibit spreading

.sodium thiosulfate

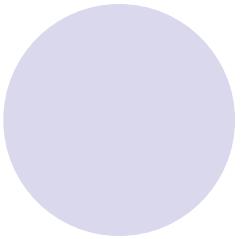
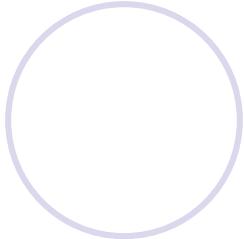
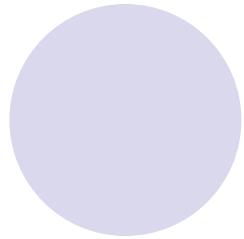
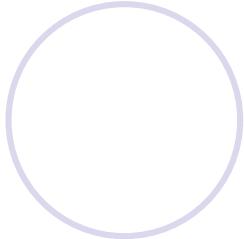
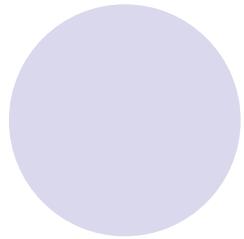
.sodium tetrathionate reduce effect of heavy metal toxicity.

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

(3) **Indirect methods**

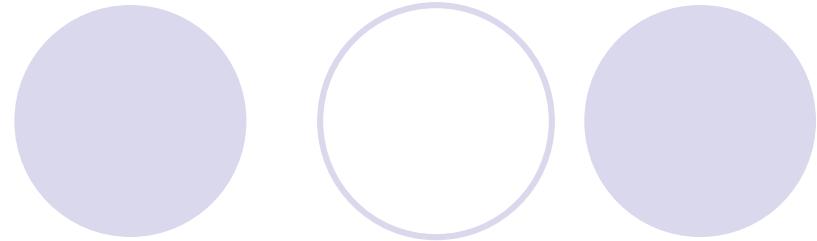
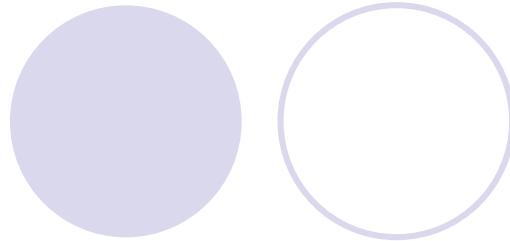
PDA: potato dextrose agar

MEA: malt extract agar



## **(B) Role of fungi in food**

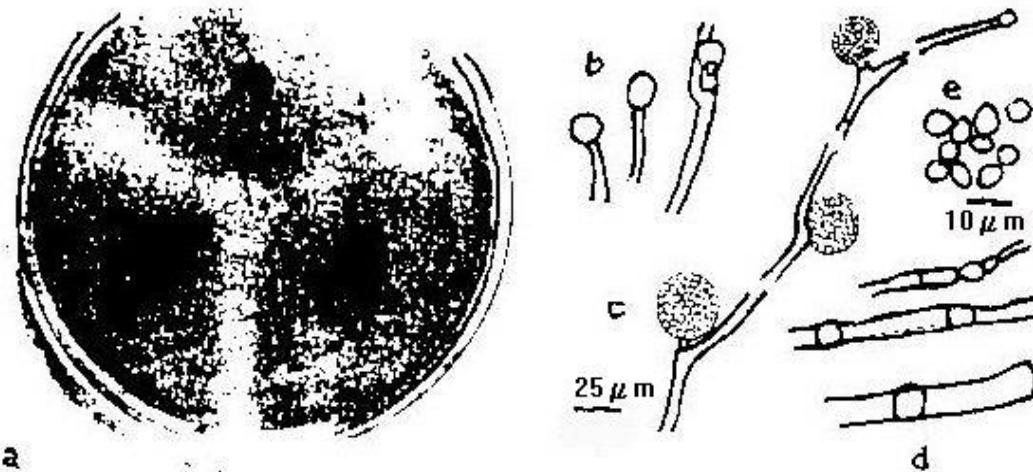
- Spoilage
- Health hazards (mycotoxins)
- fermentation

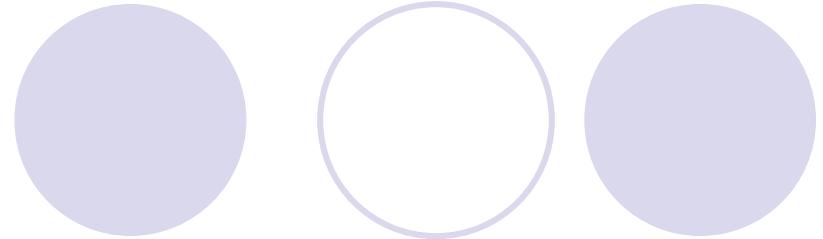
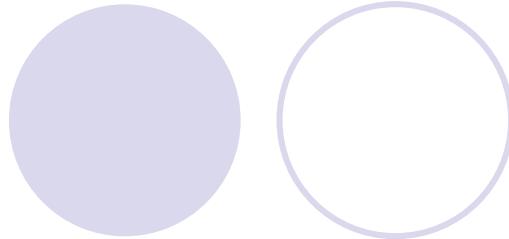


## (C) Molds important in foods

(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

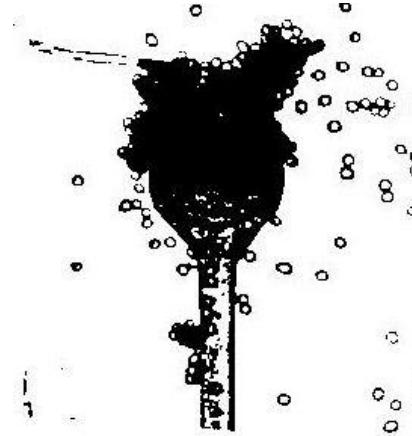
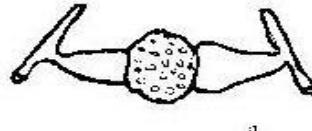
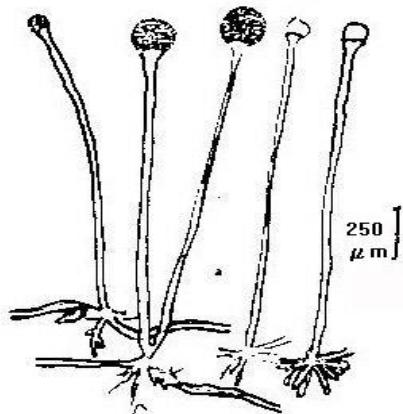
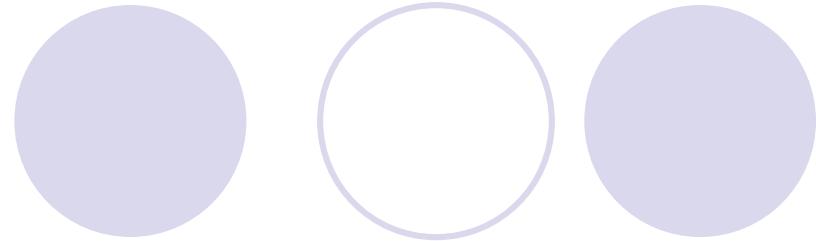
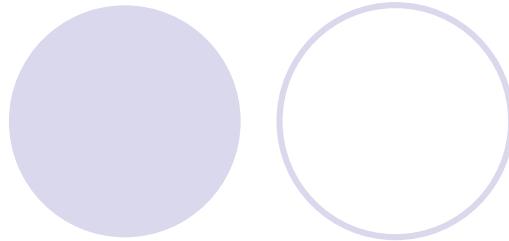




***Rhizopus*** -類似 *Mucor*，有Rhizoid，亦為糖化菌一種

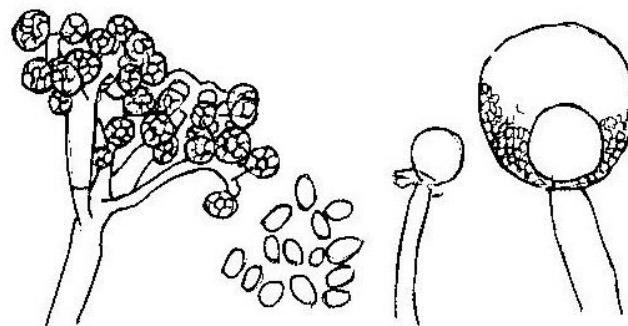
*R.stolonifer*: bread mold

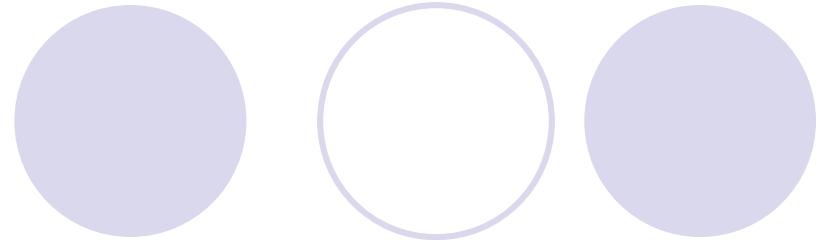
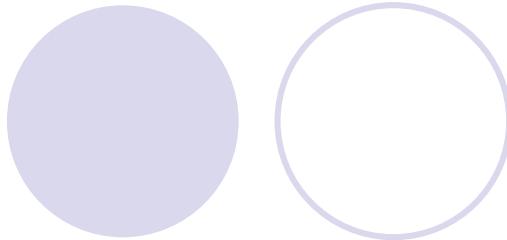
*R.oligosporus*: Tempeh



***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

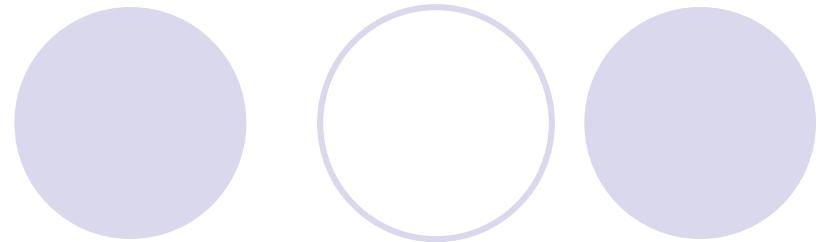
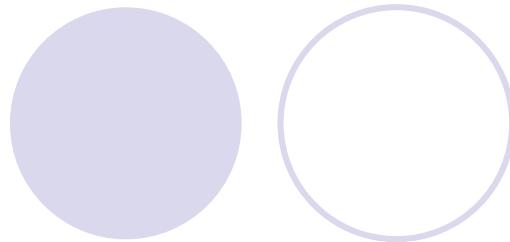
### *Byssochlamys*

Some spores heat resistant → survive heating processing  
growth in reduced O<sub>2</sub> → produce pectic enzyme → soft texture of  
canned  
& fruits → spoilage

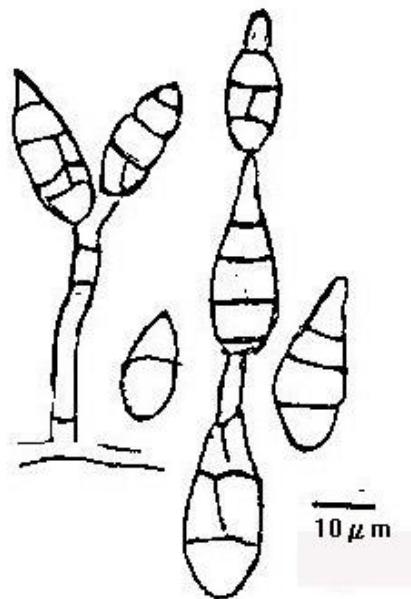
### *B. fulva* : heat resistant spore

(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

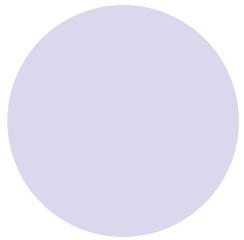
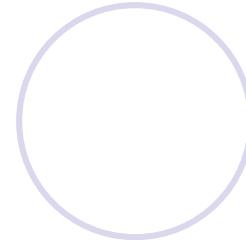
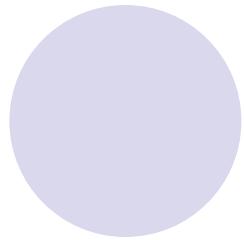
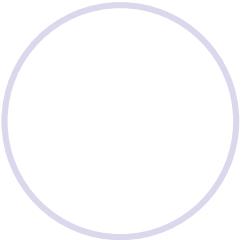
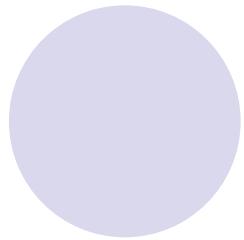


黑色孢子

plant pathogens

spoilage of tomato in the field

*A.alternata* produce mycotoxins (alternarin)



## *Aspergillus* 麴黴

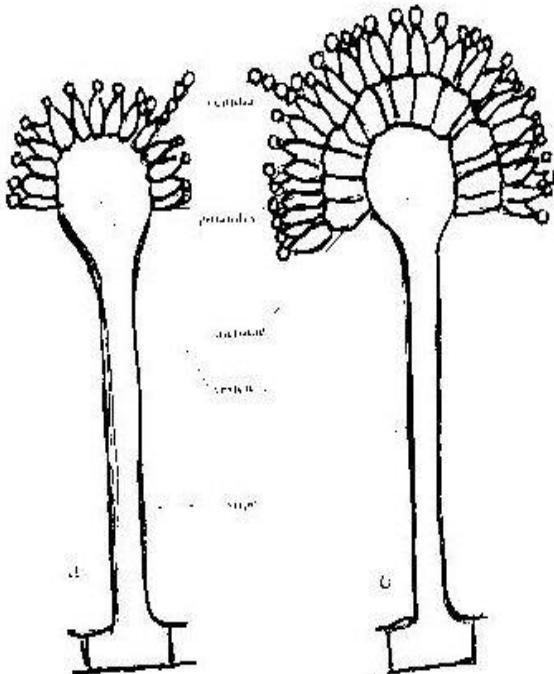
*A. niger*: black conidia, citric acid.

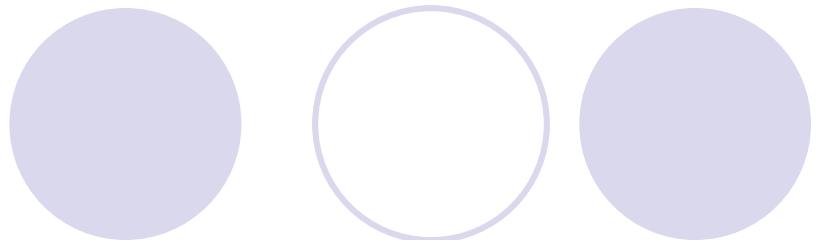
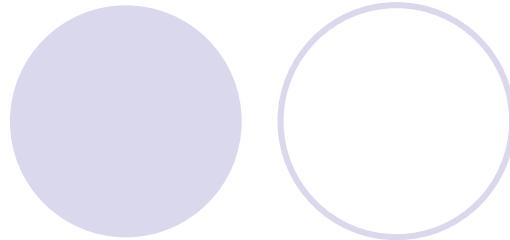
*A. flavus & A. parasiticus*: yellow-green aflatoxin

*A. candidus*: white conidia

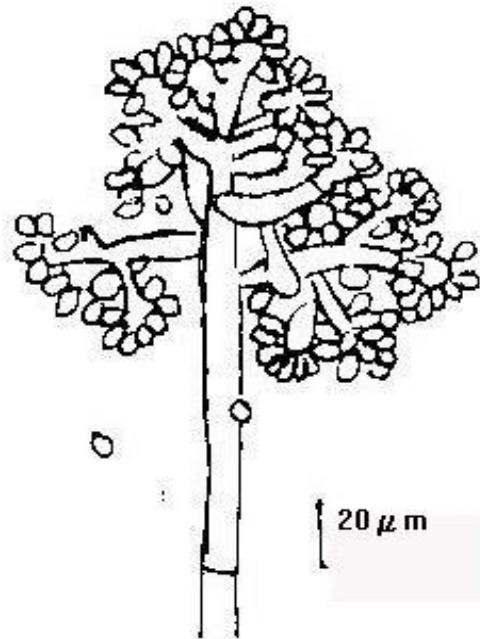
*A. ochraceus*: yellow-brown conidia, dry food ochratoxin.

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





## *Botrytis* 蠶絲菌屬

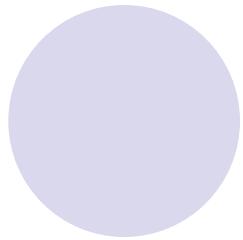
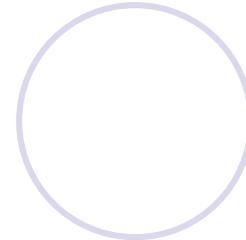
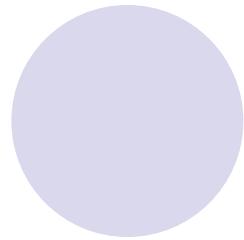
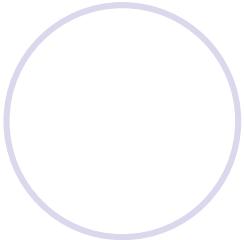
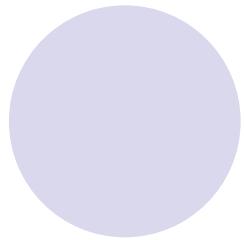


*B. cinerea*

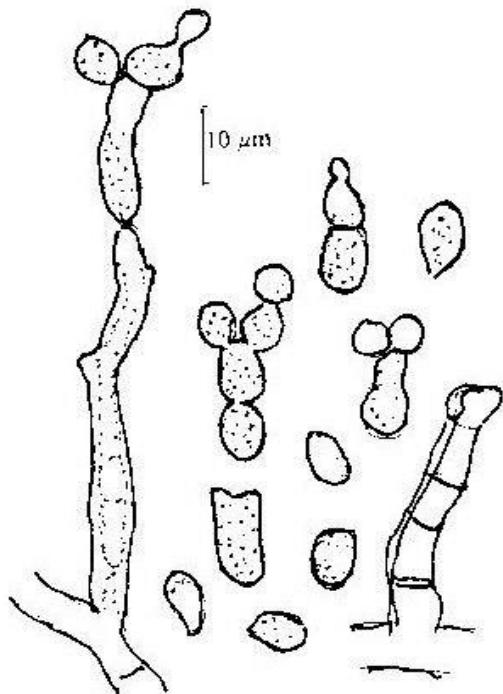
如樹枝狀分支

灰色

fruit & vegetable spoilages



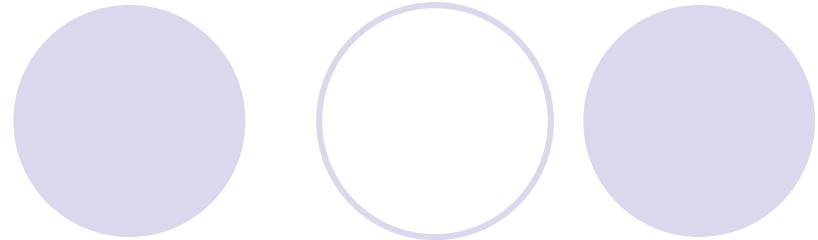
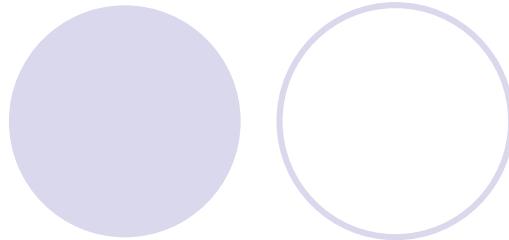
## *Cladosporium* 分枝黴菌



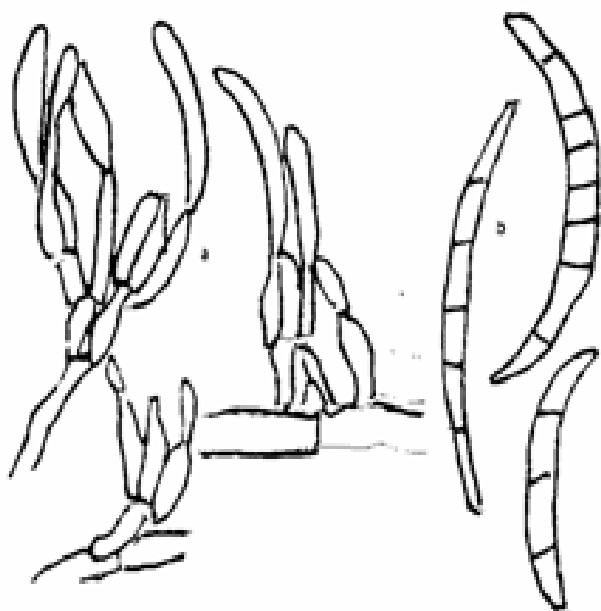
分隔，由之產生厚膜孢子

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

*C. cladosporioides*: grains, flour, vegetable



## *Fusarium* 鐮刀黴菌屬



plant pathogens

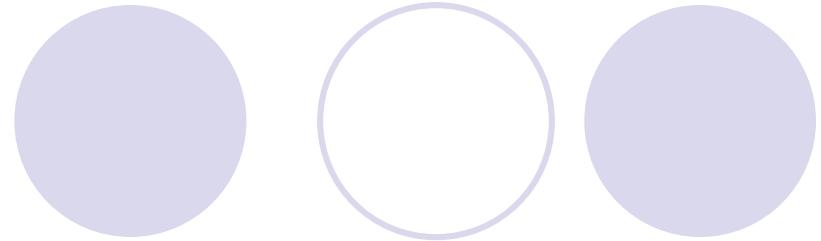
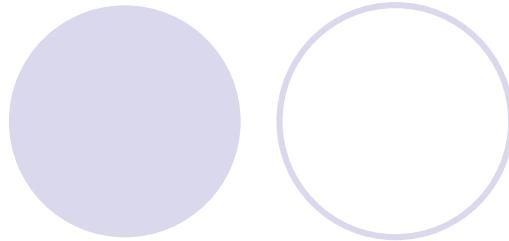
*F.moniliforme*: gibberellic acid

一種植物生長激素

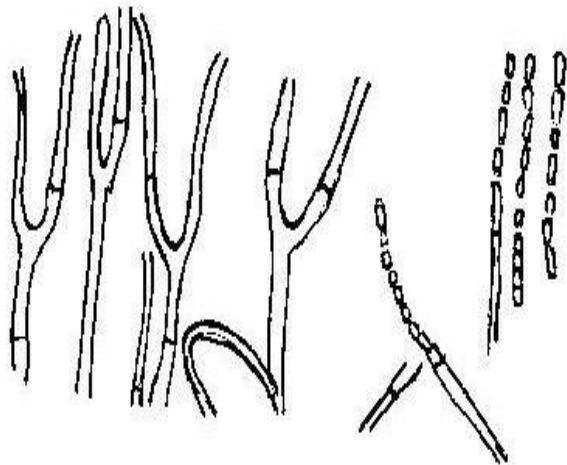
*F.oxysporium*

*F.roseum* Zearalenone

*F.tricinctum* (mycotoxin)

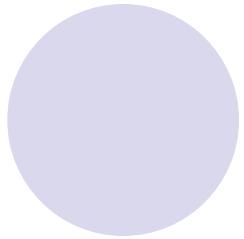
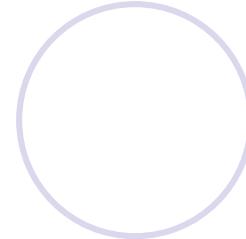
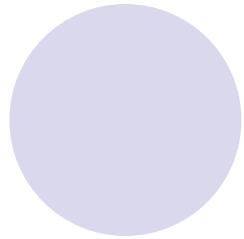
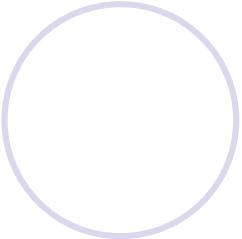
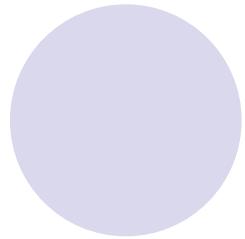


## *.Geotrichum*

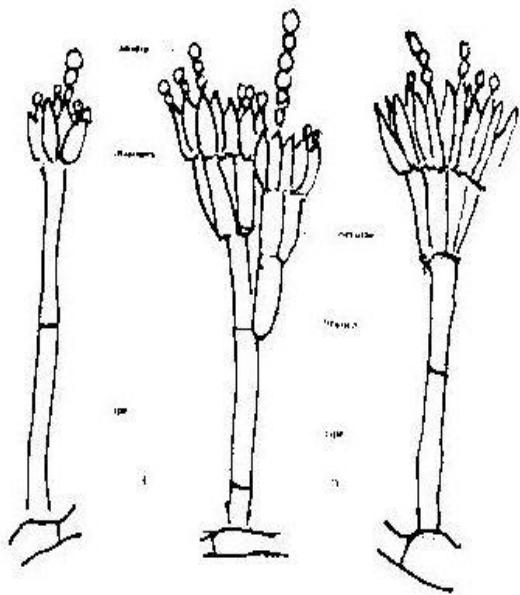


yeastlike, white

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



## *Penicillium* 青黴菌屬



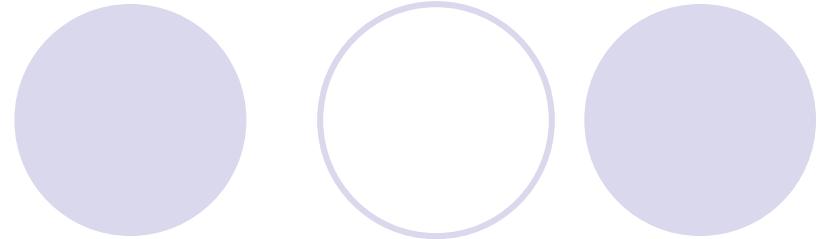
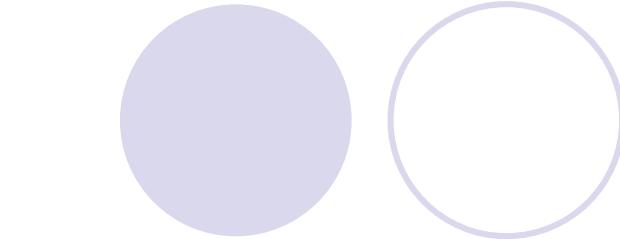
*P.chrysogenum*: produce gluconic acid, protease, penicillin.

*P.camemberti*: Camembert cheese

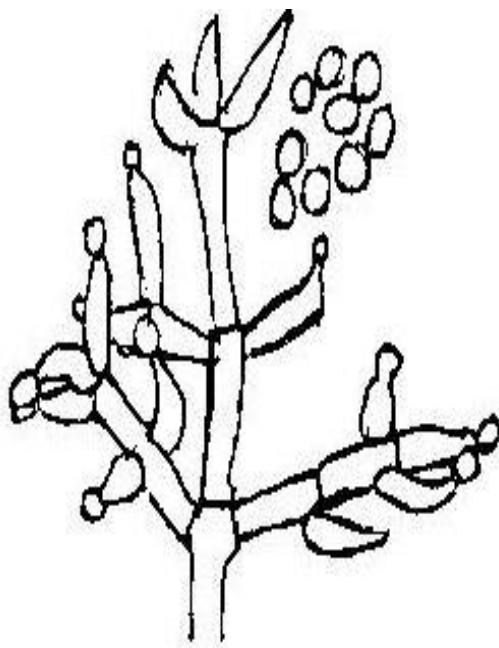
*P.cyclopium*: penicillic acid (mycotoxin)

*P.viridicatum*: citrinin ochratoxin

*P.expansum*: patulin (apple)

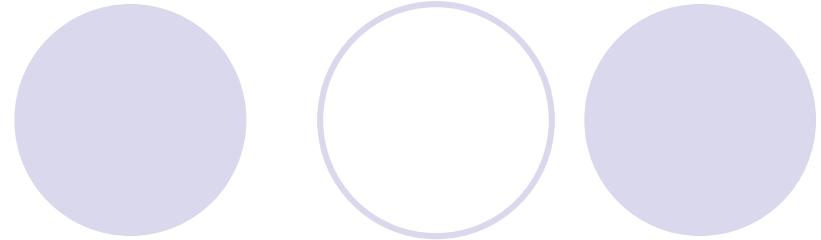
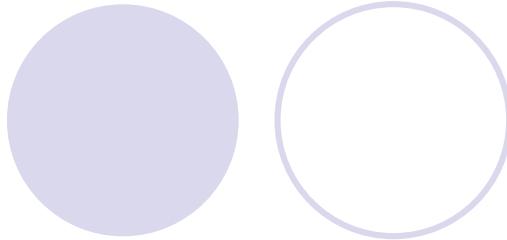


## *. Trichoderma*



*T. viride*

*T. roseum*:cellulolytic



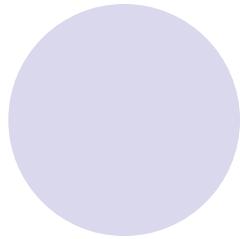
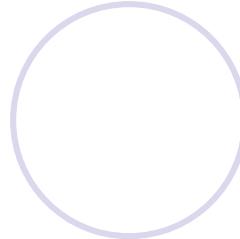
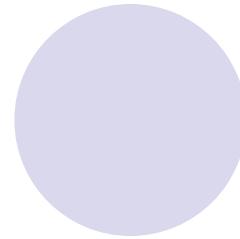
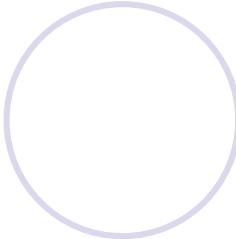
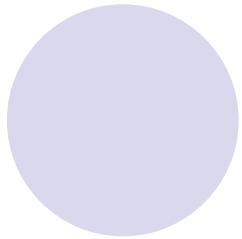
## Yeast

有性生殖-接合生殖

無性生殖-分裂，出芽生殖

菌落多為黃色，少數褐、灰，(粉)紅

(1) *Ascomycetes* : 有性生殖及無性生殖均有



## *.Debaryomyces*

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

film forming yeast in brine

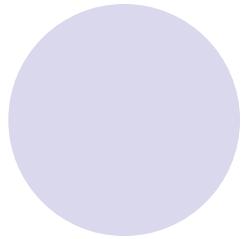
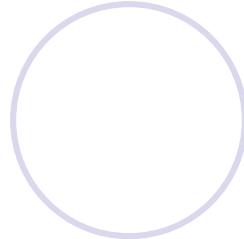
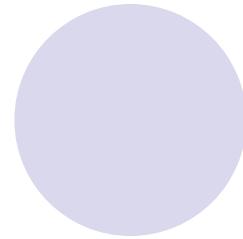
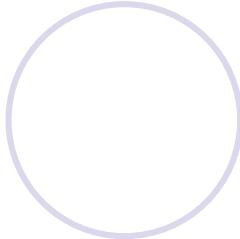
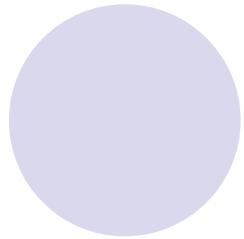
slime on salted meats

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

## *.Hanseniaspora*

inositol & pantothenate: growth factor.

can be used to assay for these compounds.



## *.Hansenula*

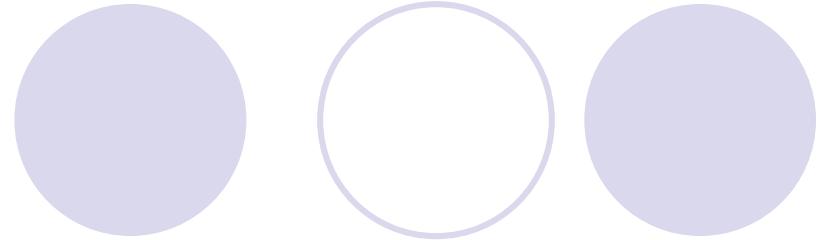
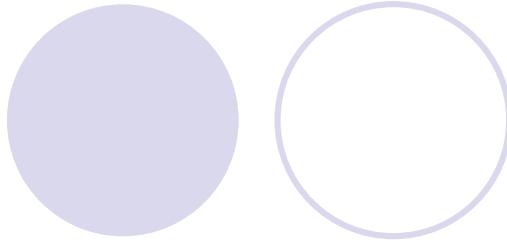
assimilate nitrate.

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.

## *.Saccharoymyces*

sugar fermentation, not use lactose & nitrate.

*S. cerevisiae* & *S. uvarum*

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

*S. bailii*: xerotolerant

*S. bisporus*: xerophilic