KLASIFIKASI, FISIOLOGI KUMAN

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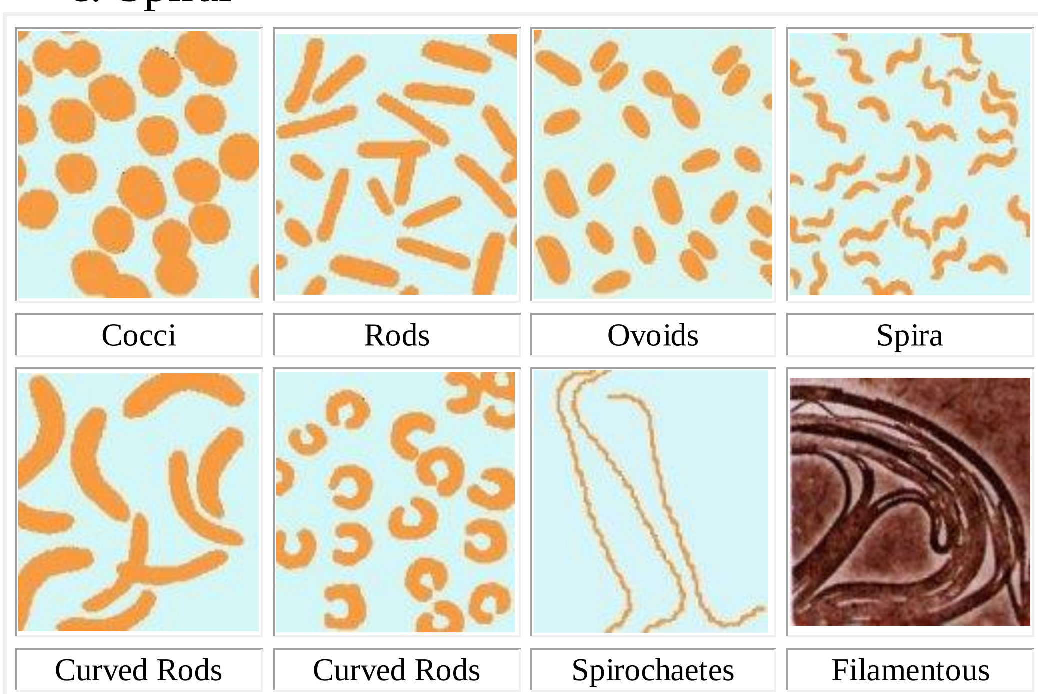
Klasifikasi Bakteri

Bakteri dapat diklasifikasi berdasarkan:

1. Bentuk dan morfologi
   a. Kokus

   b. Basilus

   c. Spiral



2. Berdasarkan bahan makanan
3. Berdasarkan pewarnaan Gram, Tahan Asam, dll
4. Berdasarkan perbedaan struktur dinding sel

Taxonomi

(a) A group or category of related organisms

(b) For example, at the lowest level, *species* is a taxonomic category as is genera and all the way on up to kingdom and domain

(c) These groups become increasingly inclusive as they become larger, going from species to kingdom or domain

(d) Two key characteristic of taxa are that

- (i) Members of lower level taxa (e.g., species) are more similar to each other than are members of higher level taxa (e.g., kingdoms or domain)
- (ii) Members of specific taxa are more similar to each other than any are to members of different specific taxa found at the same hierarchical level (e.g., humans are more similar to apes, i.e., comparison between species, than either is similar to, for example, *Escherichia coli*)
- (iii) Thus, once you know that two individuals are members of the same taxon, you can infer certain similarities between the two organisms (e.g., all members of Family *Enterobacteriaceae* are facultatively anaerobic, Gram-negative rods)

(e) Note that taxa are dynamic, changing as our knowledge of organisms and evolutionary relationships change.

(2) Binomial nomenclature

(a) Organisms are named using binomial nomenclature (viruses are exceptions)

(b) Binomial nomenclature employs the names of the two lower level taxa, genus and species, to name a species

(c) We've been through this, but conventions when using binomial nomenclature include:

- (i) Genus comes before species (e.g., *Escherichia coli*)
- (ii) Genus name is always capitalized (e.g., *Escherichia*)
- (iii) Species name is never capitalized (e.g., *coli*)
- (iv) Both names are always either italicized or underlined (e.g., *Escherichia coli*)
- (v) The genus name may be used alone, but not the species name (i.e., saying or writing "*Escherichia*," alone is legitimate while saying or writing "*coli*" is not)
- (vi) The genus name may be abbreviated but
  - It must be used first without abbreviation
  - If abbreviated it must be used with the species name (no *E*. all by itself)
  - It must be abbreviated unambiguously
  - If abbreviating as the first letter of the genus is unambiguous, then abbreviating as the first letter is what one does (e.g., *Escherichia* abbreviated as *E*. but only if no other genera considered also starts with E)

- Genus abbreviations are only used in conjunction with the species name (i.e., *E. coli*)

(3) Strain

(a) When considering microorganism species, a category (not usually considered a taxonomic one) found below the level of species is strain

(b) A strain in some ways is equivalent to a breed or a subspecies among plants or animals

(c) Two members of the same strain are more similar to each other than either is to an individual that is a member of a different strain, even if all three organisms are members of the same species

(4) Bacterial species

(a) "A bacterial species is defined by the similarities found among its members. Properties such as biochemical reactions, chemical composition, cellular structures, genetic characteristics, and immunological features are used in defining a bacterial species. Identifying a species and determining its limits presents the most challenging aspects of biological classification—for any type of organism."

(b) A formal means of distinguishing bacterial species is by employing a dichotomous key to guide the selection of tests used to efficiently determine those bacterial properties most relevant to bacterial identification

(5) The five-kingdom system

(a) The five-kingdom system was first proposed in 1969 and is showing its age

(b) It posits the existence of five kingdoms (kingdom therefore being the highest/most inclusive taxonomic category in this system)

(c) The five kingdoms include:

  (i) Plantae (the plants)
  (ii) Fungi (the fungi)
  (iii) Animalia (the animals)
  (iv) Protista (the unicellular eucaryotes)
  (v) Monera (the prokaryotes)

(d) Below we will walk through the five-kingdom kingdoms in which most microorganisms are found, before proposing alternatives to the five-kingdom system.

(6) Kingdom Monera

(a) Your text differentiates Monera into three categories (without assigning a taxonomic category to the distinctions)

(b) Included are the eubacteria, the cyanobacteria, and the archaeobacteria

(c) As we will see, these distinctions are more phenotypic than they are evolutionary (i.e., a cyanobacteria is a eubacteria, and neither is an archaeobacteria)

(i) the eubacteria are our common, every-day bacteria, some of which are disease-causing; also the taxon from which mitochondria originated
(ii) the cyanobacteria are photosynthetic eubacteria, the taxon from which chloroplasts originated
(iii) the archaeobacteria are distinctive in their adaptation to extreme environments (e.g., very hot, salty, or acidic) though not all archaeobacteria live in extreme environments

(7) Kingdom Protista

(a) Protista, like Monera, consists mostly of unicellular organisms
(b) Distinctively, however, the members of kingdom Protista are all eucaryotic while the members of kingdom Monera are all prokaryotic
(c) Some members of protista are multicellular, however
(d) Kingdom protista represents a grab bag, essentially the place where species are classified when they are not classified as either fungi, animals, or plants (kingdom Protista is a paraphyletic taxon for those of you familiar with the term)
(e) Note that most members of protista are additionally more or less aquatic

(8) Kingdom Fungi

(a) Unlike protists, the eukaryotic fungi are typically non-aquatic species
(b) They additionally are nutrient absorbers plus have additional distinctive features
(c) There do exist unicellular fungi, which we call yeasts

(9) The three-domain system

(a) Less than ten years after the creation of the five-kingdom system of classification, microbiologist Carl Woese was instrumental in establishing a new system of classification which a little over ten years later became the three-domain system
(b) This system was basically accepted by microbiologists during the late 1980s, early 1990s and is increasing the system of choice of non-microbiologist biologists
(c) It even made the headlines a few years back with the declaration that a "new" form or life had been discovered (a.k.a., archaeobacteria, which had been discovered years previously and had been shown to be a "different" form of cellular life in the late 1970s, but one member of which was DNA sequenced in full in the late 1990s supplying the genesis of the headlines; with a complete sequence we obtained unambiguous confirmation of just how different from bacteria and eucaryotes these beasts truly are) [completely sequenced Archaeal genomes]

(10) Domain

(a) The domain is a taxonomic category that, depending on point of view, is either above the level of kingdom (i.e., includes kingdoms within it) or supercedes the kingdom

(b) Regardless of viewpoint, the domain system contains three members
- (i) Eukaryotes (domain Eukarya)
- (ii) Eubacteria (domain Bacteria)
- (iii) Archaebacteria (domain Archaea)

(c) A fourth domain or domain-like taxon, called the Urkaryotes, represents eukaryotes prior to their establishment of endosymbioses with eubacteria, i.e., mitochondria

(11) Domain Archaea

(a) Domain archaea is only minimally dealt with by your text in the chapters we will cover because
- (i) these organisms are both less-well characterized than members of domain Bacteria
- (ii) correlated with reason (i) (i.e., this latter is the reason for the former), the Archaea, unlike the Bacteria, do not cause human disease

(b) The Archaea are surprisingly diverse (perhaps not *surprisingly*, they show diversity on the order of that displayed by members of domain Bacteria)

(c) Typically they are distinguished by the environments in which they live as well as by their biochemical attributes

(d) For example,
- (i) Methanogens live in anaerobic environments, breaking down organism molecules and giving rise to methane (i.e., swamp gas and cow farts) [methanogen home page]
- (ii) Extreme halophiles live in highly saline environments such as inland seas as well as salt-preserved foods [halophilic microorganisms]
- (iii) Extreme thermoacidophiles live in geothermally heated waters (e.g., hot springs) [thermophilic microorganisms]

(12) Extremozymes

(a) These are the highly heat-stabilized enzymes employed by extremely thermophilic bacteria

(b) Such enzymes can be employed industrially, or even in down to earth applications such as cleaning clothing in high temperature washes (i.e., your washing machine on the hot cycle)

(13) Dichotomous key

(a) A means of assigning an organism to a specific taxonomic category typically involves the use of specific criteria that may be posed as questions (e.g., what does the organism look like? etc.)

(b) Relevant criteria may be arranged as a dichotomous key

(c) In a dichotomous key questions are arranged hierarchically (just as taxonomic categories are) with more general questions (i.e., those arranging organisms into large categories) are asked first, with questions becoming more specific (better suited to arranging organisms into more specific taxa) asked subsequently

(d) In addition, questions are dichotomous, meaning that they each have two possible answers, with each answer distinguishing the organisms as well as the path to the next question

(14) Numerical taxonomy

(a) "Numerical taxonomy is based on the idea that increasing the number of characteristics of organisms that we observe increases the accuracy with which we can detect similarities among them. If the characteristics are genetically determined, the more characteristics two organisms share, the closer their evolutionary relationship."

(b) So, basically, numerical taxonomy involves taking a good, long look at the characteristics of two or more organisms, seeing how often these characteristics correspond, and, typically, using a computer to keep track of what you are doing

(c) That is, this is a dichotomous-tree-like device that is less easy to walk through manually so employs a computer to crunch the data

(d) ["Numerical taxonomy in the broad sense is the greatest advance in systematics since Darwin or perhaps since Linnaeus. It has stimulated several new areas of growth, including numerical phylogenetics, molecular taxonomy, morphometrics, and numerical identification. It has wide application outside systematic biology. Landmarks and trends are important aspects of numerical taxonomy. In microbiology, the program of numerical taxonomy has been successful, as indicated by the preponderance of papers describing numerical relationships in the International Journal of Systematic Bacteriology." Thirty Years of Numerical Taxonomy by P. H. A. Sneath, Syst. Biol. 44(3):281--298, 1995]

Fisiologi Pertumbuhan Kuman

Sama seperti mahluk hidup yang lain, kuman memerlukan makan untuk kelangsungan hidup, bahan-bahan tersebut antara lain:

Table 1. Major elements, their sources and functions in bacterial cells.

Element	**% of dry weight**	**Source**	**Function**
Carbon	50	organic compounds or CO_2	Main constituent of cellular material
Oxygen	20	H_2O, organic compounds, CO_2, and O_2	Constituent of cell material and cell water; O_2 is electron acceptor in aerobic respiration
Nitrogen	14	NH_3, NO_3, organic compounds, N_2	Constituent of amino acids, nucleic acids nucleotides, and coenzymes
Hydrogen	8	H_2O, organic compounds, H_2	Main constituent of organic compounds and cell water
Phosphorus	3	inorganic phosphates (PO_4)	Constituent of nucleic acids, nucleotides, phospholipids, LPS, teichoic acids
Sulfur	1	SO_4, H_2S, S^o, organic sulfur compounds	Constituent of cysteine, methionine, glutathione, several coenzymes
Potassium	1	Potassium salts	Main cellular inorganic cation and cofactor for certain enzymes
Magnesium	0.5	Magnesium salts	Inorganic cellular cation, cofactor for certain enzymatic reactions
Calcium	0.5	Calcium salts	Inorganic cellular cation, cofactor for certain enzymes and a component of endospores
Iron	0.2	Iron salts	Component of cytochromes and certain nonheme iron-proteins and a cofactor for some enzymatic reactions

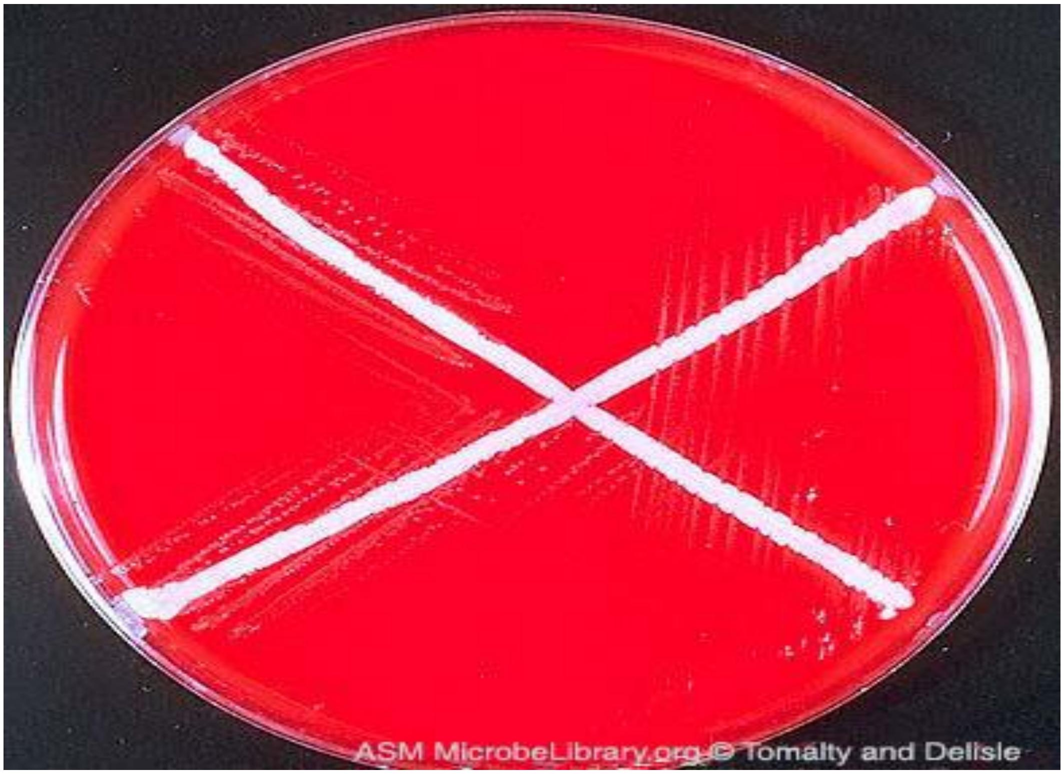
Disamping itu kuman juga memerlukan:

1. Air
   Kuman memerlukan kadar air yang cukup tinggi untuk pertumbuhannya, karena air berperan sebagai pengantar bahan gizi yang diperlukan kuman dan pembuang zat-zat yang tidak diperlukan oleh tubuh, melancarkan reaksi metabolic.

2. Faktor pertumbuhan
   Bakteri heterotroph tidak dapat tumbuh jika dalam media pertumbuhan tidak ditambahkan satu atau beberapa faktor pertumbuhan seperti yeast, darah, vitamin B kompleks, asam amino: purin dan pirimidin.

Table 2. Common vitamins required in the nutrition of certain bacteria.

Vitamin	Coenzyme form	Function
p-Aminobenzoic acid (PABA)	-	Precursor for the biosynthesis of folic acid
Folic acid	Tetrahydrofolate	Transfer of one-carbon units and required for synthesis of thymine, purine bases, serine, methionine and pantothenate
Biotin	Biotin	Biosynthetic reactions that require CO_2 fixation
Lipoic acid	Lipoamide	Transfer of acyl groups in oxidation of keto acids
Mercaptoethane-sulfonic acid	Coenzyme M	CH_4 production by methanogens
Nicotinic acid	NAD (nicotinamide adenine dinucleotide) and NADP	Electron carrier in dehydrogenation reactions
Pantothenic acid	Coenzyme A and the Acyl Carrier Protein (ACP)	Oxidation of keto acids and acyl group carriers in metabolism
Pyridoxine (B_6)	Pyridoxal phosphate	Transamination, deamination, decarboxylation and racemation of amino acids
Riboflavin (B_2)	FMN (flavin mononucleotide) and FAD (flavin adenine dinucleotide)	Oxidoreduction reactions
Thiamine (B_1)	Thiamine pyrophosphate (TPP)	Decarboxylation of keto acids and transaminase reactions
Vitamin B_{12}	Cobalamine coupled to adenine nucleoside	Transfer of methyl groups
Vitamin K	Quinones and napthoquinones	Electron transport processes



Gambar 1 : *Staphylococcus aureus* yang dapat tumbuh pada Agar darah.

3. Oksigen untuk proses metabolisme
   Berdasarkan kebutuhan akan oksigen kuman dibagi menjadi:
   a. Obligat anaerob: tidak dapat tumbuh jika ada oksigen
   b. Aerotoleran anaerob : tidak akan mati jika terpapar oksigen
   c. Fakultatif anaerob : dapat tumbuh pada keadaan ada/tidak ada oksigen
   d. Obligat aerob : tumbuh jika ada oksigen
   e. Mikroaerolitik : tumbuh baik pada tekanan oksigen rendah

Table 3. Terms used to describe O_2 Relations of Microorganisms.

		Environment	
Group	**Aerobic**	**Anaerobic**	**O_2 Effect**
Obligate Aerobe	Growth	No growth	Required (utilized for

			aerobic respiration)
Microaerophile	Growth if level not too high	No growth	Required but at levels below 0.2 atm
Obligate Anaerobe	No growth	Growth Toxic	
Facultative Anaerobe (Facultative Aerobe)	Growth	Growth	Not required for growth but utilized when available
Aerotolerant Anaerobe	Growth	Growth	Not required and not utilized

4. Potensial oksidasi reduksi
   Untuk bakteri yang kontak dengan udara 0.2 sampai 0.4 volt pH 7, bakteri anaerob -0.2 Volt.

5. Temperatur
   Berdasarkan kisaran temperatur lingkungan dimana bakteri dapat hidup, maka bakteri dibagi menjadi 3 golongan:
   a. Psikotropik : hidup dilingkungan yang bersuhu -5°C sampai 30°C optimum pada suhu 10-20°C
   b. Mesofilik : hidup dilingkungan yang bersuhu 10-40°C optimum pada suhu suhu 20-40°C
   c. Termofilik : hidup dilingkungan yang bersuhu 28-80°C optimum pada suhu suhu 50-60°C

Table 4. Terms used to describe microorganisms in relation to temperature requirements for growth.

	Temperature for growth (degrees C)			
Group	**Minimum**	**Optimum**	**Maximum**	**Comments**

Psychrophile	Below 0	10-15	Below 20	Grow best at relatively low T
Psychrotroph	0	15-30	Above 25	Able to grow at low T but prefer moderate T
Mesophile	10-15	30-40	Below 45	Most bacteria esp. those living in association with warm-blooded animals
Thermophile*	45	50-85	Above 100 (boiling)	Among all thermophiles is wide variation in optimum and maximum T

*For "degrees" of thermophily see text and graphs above

Table 5a. Minimum, maximum and optimum temperature for growth of certain bacteria and archaea.

	Temperature for growth (degrees C)		
Bacterium	**Minimum**	**Optimum**	**Maximum**
Listeria monocytogenes	1	30-37	45
Vibrio marinus	4	15	30
Pseudomonas maltophilia	4	35	41
Thiobacillus novellus	5	25-30	42
Staphylococcus aureus	10	30-37	45
Escherichia coli	10	37	45
Clostridium kluyveri	19	35	37
Streptococcus pyogenes	20	37	40
Streptococcus pneumoniae	25	37	42
Bacillus flavothermus	30	60	72
Thermus aquaticus	40	70-72	79
Methanococcus jannaschii	60	85	90
Sulfolobus acidocaldarius	70	75-85	90
Pyrobacterium brockii	80	102-105	115

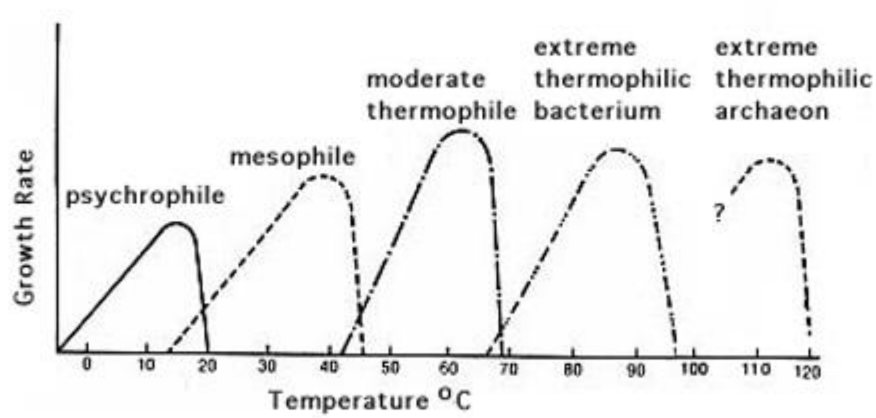
Table 5b. Optimum growth temperature of some procaryotes.

Genus and species	Optimal growth temp (degrees C)
Vibrio cholerae	18-37
Photobacterium phosphoreum	20
Rhizobium leguminosarum	20
Streptomyces griseus	25

Rhodobacter sphaeroides	25-30
Pseudomonas fluorescens	25-30
Erwinia amylovora	27-30
Staphylococcus aureus	30-37
Escherichia coli	37
Mycobacterium tuberculosis	37
Pseudomonas aeruginosa	37
Streptococcus pyogenes	37
Treponema pallidum	37
Thermoplasma acidophilum	59
Thermus aquaticus	70
Bacillus caldolyticus	72
Pyrococcus furiosus	100

Table 5c. Hyperthermophilic Archaea.

	Temperature for growth(degrees C)			
Genus	**Minimum**	**Optimum**	**Maximum**	**Optimum pH**
Sulfolobus	55	75-85	87	2-3
Desulfurococcus	60	85	93	6
Methanothermus	60	83	88	6-7
Pyrodictium	82	105	113	6
Methanopyrus	85	100	110	7



6. pH
   Kuman patogen mempunyai pH optimum 7.2-7.6

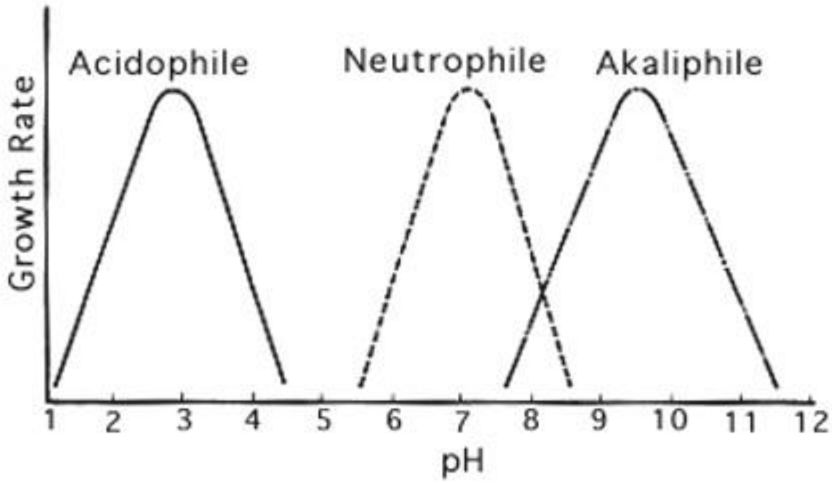


Table 6. Minimum, maximum and optimum pH for growth of certain procaryotes.

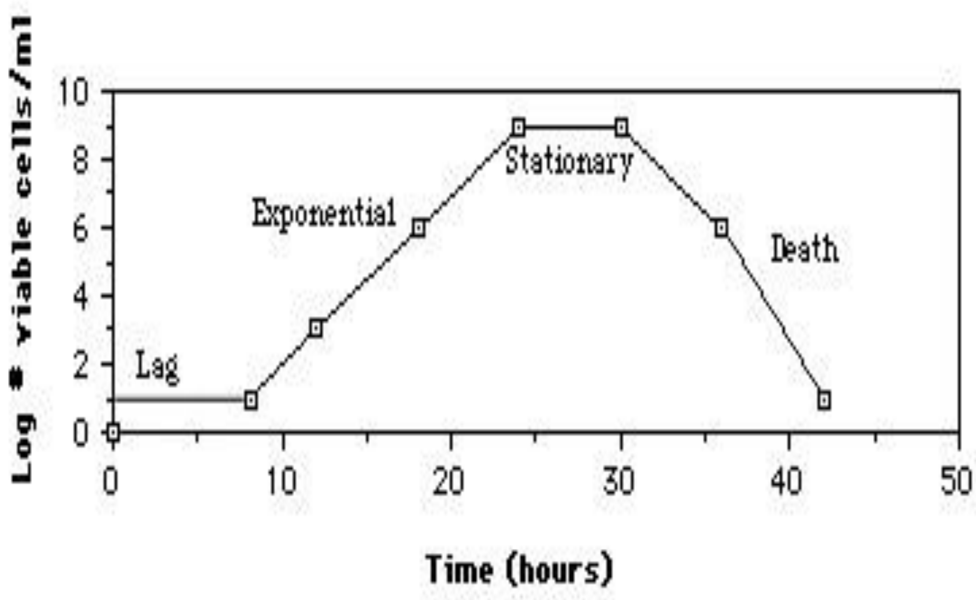
Organism	Minimum pH	Optimum pH	Maximum pH
Thiobacillus thiooxidans	0.5	2.0-2.8	4.0-6.0
Sulfolobus acidocaldarius	1.0	2.0-3.0	5.0
Bacillus acidocaldarius	2.0	4.0	6.0
Zymomonas lindneri	3.5	5.5-6.0	7.5
Lactobacillus acidophilus	4.0-4.6	5.8-6.6	6.8
Staphylococcus aureus	4.2	7.0-7.5	9.3
Escherichia coli	4.4	6.0-7.0	9.0
Clostridium sporogenes	5.0-5.8	6.0-7.6	8.5-9.0
Erwinia caratovora	5.6	7.1	9.3
Pseudomonas aeruginosa	5.6	6.6-7.0	8.0
Thiobacillus novellus	5.7	7.0	9.0
Streptococcus pneumoniae	6.5	7.8	8.3
Nitrobacter sp	6.6	7.6-8.6	10.0

Kuman bereproduksi dengan cara :

1. Pembelahan
   Umumnya kuman berkembang biak secara amitogenesis, membelah menjadi 2 bagian, waktu pembelahan bervariasi antara 20 menit sampai 15 jam
2. Pembentukan tunas cabang
   Kuman membentuk tunas, tunas akan memisahkan diri
3. Pembentukan filamen
   Sel kuman akan mengeluarkan filamen, kromosom akan memasuki filamen. Filamen terputus-putus. Tiap bagian akan membentuk kuman baru
4. Reproduksi secara seksual
   Terjadi peleburan kromosom 2 buah bakteri akibatnya akan timbul kuman-kuman yang baru.

Fase Pertumbuhan Kuman

Apabila kuman ditumbuhkan dalam media cair kemudian diukur jumlah selnya setiap jam, maka akan didapatkan gambaran pertumbuhan kuman sebagai berikut:



a. Fase penyesuaian (lag fase)
   Berlangsung selama 2 jam, kuman belum berkembang biak, fase penyesuaian dengan lingkungan yang baru

b. Fase pembelahan (fase logaritmik atau eksponensial)

Kuman berkembang biak dengan pembelahan, jumlah kuman meningkat, berlangsung 18-24 jam. Pada pertengahan fase ini pertumbuhan kuman sangat ideal, pembelahan terjadi secara teratur.

c. Fase stationer (Stationary phase)
Dengan meningkatnya jumlah kuman, maka terjadi pula peningkatan jumlah hasil metabolisme yang bersifat toksik bagi kuman, saat ini banyak ditemukan kuman mulai mati, pertumbuhan terhambat. Pada suatu saat akan terjadi jumlah kuman yang hidup tetap sama.

d. Fase kemunduran/penurunan (period of decline)
Jumlah kuman yang hidup berkurang dan menurun. Keadaan lingkungan menjadi sangat jelek. Pada beberapa kuman timbul bentuk-bentuk jelek. (bentuk involusi)

Table 7 Generation times for some common bacteria under optimal conditions of growth.

Bacterium	**Medium**	**Generation Time (minutes)**
Escherichia coli	Glucose-salts	17
Bacillus megaterium	Sucrose-salts	25
Streptococcus lactis	Milk	26
Streptococcus lactis	Lactose broth	48
Staphylococcus aureus	Heart infusion broth	27-30
Lactobacillus acidophilus	Milk	66-87
Rhizobium japonicum	Mannitol-salts-yeast extract	344-461
Mycobacterium tuberculosis	Synthetic	792-932
Treponema pallidum	Rabbit testes	1980