# Biology

## Cellular Biology

Cell Structure

General types of cellular structure:

- Prokaryote
  (e.g., bacteria and blue-green algae)
- Eukaryote
  (e.g., plants and animals)

## Cellular Biology: Cell Structure—Prokaryotes

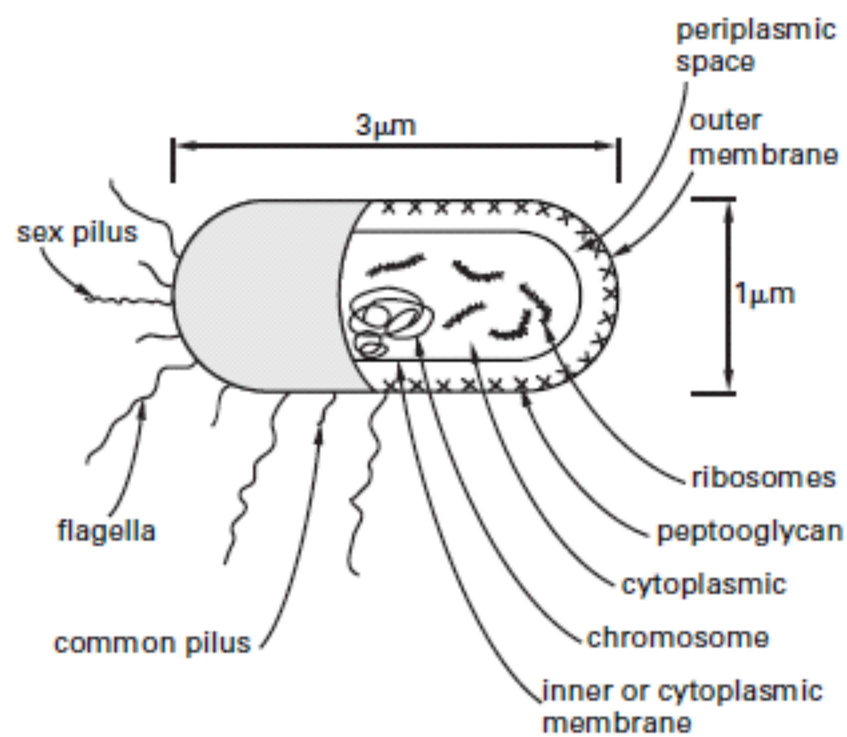
Prokaryotes:

- Single-cell organisms with a primitive nucleus that lack a confining membrane
- Reproduce asexually by binary fission (dividing in two)

Components of prokaryotic cells:

- Periplasmic space, outer membrane, protoplasm
- Chromosome
- Ribosomes
- Peptooglycan
- Pilus, flagella

*Figure 33.1 Prokaryotic Cell Features*

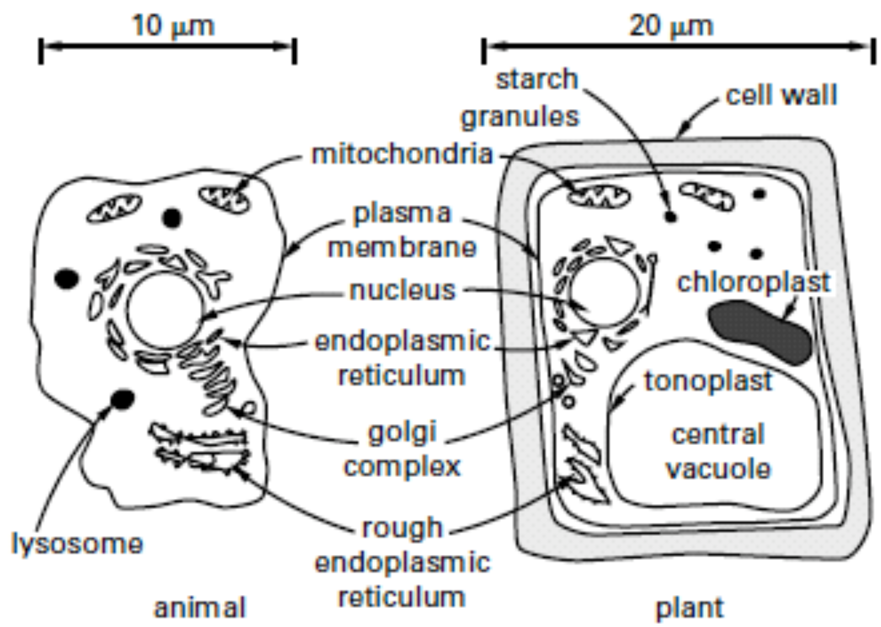


## Cellular Biology: Cell Structure—Eukaryotes

Eukaryotes:
- Much larger
- Have a definite nucleus
- Most often part of a multi-cell organism

Common components found in animal and plant cells:
- Mitochondria
- Plasma membrane
- Nucleus
- Endoplasmic reticulum
- Golgi complex

Figure 33.2 Eukaryotic Cell Features



# Biology 5-3b

## Cellular Biology: Cell Structure—Eukaryotes

Component found in animal cells only:
- Lysosomes

Components found in plant cells only:
- Chloroplast
- Tonoplast
- Central vacuole
- Starch granules
- Cell wall

## Cellular Biology: Cell Structure—Eukaryotes

Example (FEIM):
Which of the following is NOT found in a eukaryote animal cell?

(A) mitochondria
(B) nucleus
(C) chloroplast
(D) lysosome

Eukaryote animal cells do not have chlorophyll or chloroplast. Therefore, the answer is (C).

## Cellular Biology: Cell Structure—Eukaryotes

Example (FEIM):
What is the function of the tonoplast in a eukaryote plant cell?

(A) encloses the vacuole
(B) provides a specialized cell substructure (organelle) where photosynthesis takes place
(C) converts oxygen, $O_2$, to ozone, $O_3$
(D) inhibits cell division

Tonoplast encloses the vacuole. Knowledge questions of this type sometimes have possible answers that can be eliminated because they are nonsense or they are unrelated to the subject. This improves the chances of guessing correctly. One should recognize answers (C) and (D) are unrelated to cell biology structure.

Therefore, the answer is (A).

## Cellular Biology: Cell Subdivision

- **Primary subdivisions of biological organisms**

| Group | Cell structure | Properties | Constituent groups |
|---|---|---|---|
| Eucaryotes | Eucaryotic | Multicellular; extensive differentiation of cells and tissues<br>Unicellular, coenocytic or mycelial; little or no tissue differentiation | Plants (seed plants, ferns, mosses)<br>Animals (vertebrates, invertebrates)<br>Protists (algae, fungi, protozoa) |
| Eubacteria | Procaryotic | Cell chemistry similar to eucaryotes | Most bacteria |
| Archaebacteria | Procaryotic | Distinctive cell chemistry | Methanogens, halophiles, thermoacidophiles |

This table is given in the NCEES Handbook – read and understand it.

## Cellular Biology: Cell Growth

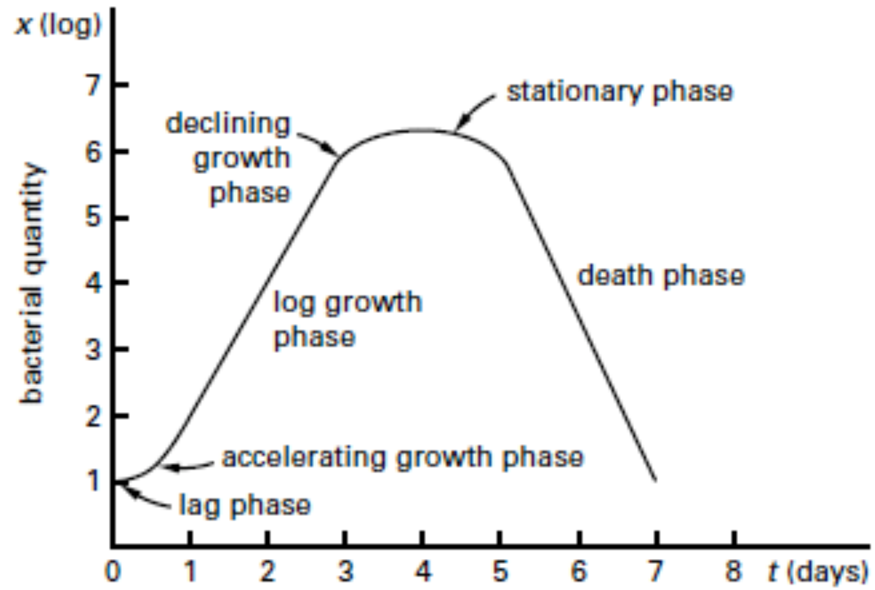
To study the cell growth rate of a species and how different conditions affect the cell growth, cell cultures are grown under controlled conditions with a controlled nutrient medium.

Growth phases of bacteria:

1. Lag phase
2. Accelerated growth phase
3. Declining growth phase
4. Stationary phase
5. Death phase

The growth pattern of a controlled culture of bacteria is shown in FERM Fig. 33.3.

*Figure 33.3 Organismal Growth in Batch Culture*



## Cellular Biology: Cell Growth

Example (FEIM):
What is most nearly the growth rate of the population in the “Organismal Growth in Batch Culture” chart in the NCEES Handbook during the log growth phase? Use base-10 logarithms.

(a) 23%/h (b) 39%/h

(c) 57%/h (d) 245%/h

The population curve at 25 h crosses the seventh line above $10^4$, so the population is $8 \times 10^4$ at 25 h. The population curve also crosses the second line above $10^3$ at 15 h, so the population is $3 \times 10^3$ at 15 h.

The graph is linear during the exponent growth phase. The equation of a straight line involving $N$ (number of bacteria) and $t$ (time in hours) is

$\log N_t = mt + \log N_0$

The curve point at $t$ = 15 h is the origin. Then, the elapsed time between the two points is 10 h.

$\log 80\,000 = m(10 \text{ h}) + \log 3000$

$m = 1.389\%/\text{h}$ (39%/h)

Therefore, the answer is (B).

## Cellular Biology: Cell Growth

The constant specific growth rate, $\mu$, applies only to the logarithmic growth phase. This quantity is normalized by dividing the growth rate, $dx/dt$, in cells per unit time, by cell concentration (the number of cells per unit volume), $x$.

$$\mu = \frac{1}{x}\,\frac{dx}{dt} \qquad 33.6$$

The growth rate can be expressed in terms of the logistic growth rate constant, $k$, and the carrying capacity, $x_\infty$, in units of grams per liter.

$$\frac{dx}{dt} = kx\left(1 - \frac{x}{x_\infty}\right) \qquad 33.8$$

This is a differential equation that can be solved for $x$ in terms of $k$, $x_\infty$, $t$, and the initial cell concentration, $x_0$.

$$x = \frac{x_0 e^{kt}}{1 - \frac{x_0}{x_\infty}\left(1 - e^{kt}\right)} \qquad 33.9$$

If $x_0 \approx 0$ at $t_0 = 0$, then the exponential nature of the growth becomes obvious.

$x = x_0 e^{kt}$

# Cellular Biology: Characteristics of Selected Microbial Cells

See FERM Table 33.3.

This table is also given in the NCEES Handbook – read and understand it.

## Cellular Biology: Stoichiometry of Selected Biological Systems

Biological reaction:

(1) Aerobic production of biomass – a biological chemical process using oxygen that reacts with an organic compound containing carbon, hydrogen, and oxygen (substrate).

In the case shown in the NCEES Handbook,

$$\underset{\text{[substrate]}}{CH_mO_n} + aO_2 + bNH_3 \rightarrow c\underset{\text{[biomass]}}{CH_\alpha O_\beta N_\delta} + d\underset{\text{[product]}}{CH_xO_yN_z} + eH_2O + fCO_2 \qquad 33.10$$

## Cellular Biology: Stoichiometry of Selected Biological Systems

The degrees of reduction represent the electrons per unit of carbon in the substrate, biomass, and product respectively relative to the valence state of the carbon in each.

$$\gamma_s = 4 + m - 2n \qquad 33.11$$

$$\gamma_b = 4 + \alpha - 2\beta - 3\delta \qquad 33.12$$

$$\gamma_p = 4 + x - 2y - 3z \qquad 33.13$$

Subscripts identify the substrate (*s*), biomass (*b*), and product (*p*). A high degree of reduction denotes a low degree of oxidation which relates the relative electrons gained (reduction) when the substrate carbon becomes biomass or product carbon.

# Cellular Biology: Stoichiometry of Selected Biological Systems

Carbon balance:

$$c + d + f = 1 \quad \text{[carbon]} \qquad 33.14$$

Nitrogen balance:

$$c\delta + dz = b \quad \text{[nitrogen]} \qquad 33.15$$

Electron balance:

$$c\gamma_b + b\gamma_p = \gamma_s - 4a \quad \text{[electron]} \qquad 33.16$$

Energy balance:

$$Q_o C\gamma_b + Q_o d\gamma_p = Q_o\gamma_s - Q_o 4a \quad \text{[energy]} \qquad 33.17$$

$Q_o$ = heat evolved per equivalent of available electrons
≈ 26.95 kcal/g of electrons

## Cellular Biology: Stoichiometry of Selected Biological Systems

Respiratory quotient (RQ) is the $CO_2$ produced per unit of $O_2$.

$$\mathrm{RQ} = \frac{f}{a} \qquad 33.18$$

The yield coefficient is *c* for grams of cells per gram substrate, $Y_{X|S}$, or *d* for grams of product per gram substrate, $Y_{X|XP}$.

Satisfying the carbon, nitrogen, and electron balances, plus knowing the respiratory coefficient and a yield coefficient, are sufficient to solve for *a*, *b*, *c*, *d*, and *f* coefficients.

## Cellular Biology: Stoichiometry of Selected Biological Systems

Biological reaction:

(2) Aerobic biodegradation of glucose – cells are formed and carbon dioxide and water are the only products

Example (FEIM):

Given the following biodegradation reaction (aerobic biodegradation of glucose with no product, ammonia nitrogen source, cell production only) and RQ = 1.1, find *a*, *b*, *c*, and *d*.

$$\underset{\text{[substrate]}}{C_6H_{12}O_6} + aO_2 + bNH_3 \rightarrow \underset{\text{[cells]}}{cCH_{1.8}O_{0.5}N_{0.2}} + dCO_2 + eH_2O \qquad 33.22$$

The variables and equations are slightly different than the one-product case, but the solution method is essentially the same.

Carbon balance: $6 = c + d$

Nitrogen balance: $b = c\delta = c(0.2)$

There is no product, only the biomass, so the nitrogen in the ammonia equals the nitrogen in the biomass (cell).

Electron balance:

$\gamma_s = 4 + m - 2n = 4 + 12 - (2)(6) = 4$

The substrate (glucose) can be calculated or read off the composition data for biomass and selected organic compounds table in the NCEES Handbook.

## Cellular Biology: Stoichiometry of Selected Biological Systems

The degree of reduction of the cell is calculated from the equation for the reaction. Note that molecules contain only whole numbers of any element, but stoichiometry uses fractional numbers to represent the mixture of different molecules in the cell after the reaction.

$$\begin{aligned} \gamma_b &= 4 + \alpha - 2\beta - 3\delta \\ &= 4 + 1.8 - (2)(0.5) - (3)(0.2) \\ &= 4.2 \end{aligned}$$

There is no product, and there are six carbon atoms in the substrate, so the electron balance equation is

$$c\gamma_b = 6\gamma_s - 4a$$

$$c(4.2) = (6)(4) - 4a$$

There are now four equations and four unknowns, and the equations can be solved to get the results in the NCEES Handbook (with some rounding differences).

$$a = 1.94$$

$$b = 0.77$$

$$c = 3.88$$

$$d = 2.13$$

# Cellular Biology: Stoichiometry of Selected Biological Systems

Biological reactions:

(3) Anaerobic biodegradation of organic wastes with incomplete stabilization

(4) Anaerobic biodegradation of organic wastes with complete stabilization

Calculations involving the anaerobic reactions are similar to the aerobic cases already discussed.

# Biology 5-8a

## Toxicology

Toxic exposure – A toxic substance has to enter the body before it causes toxicity.

- Dermal absorption
- Inhalation
- Ingestion
- Absorption through the eye

## Toxicology

Systemic effects – Depends on level of exposure and the toxic substance.

- Exposure must exceed the body’s ability to excrete the substance and/or render it harmless.
- The situation is aggravated when the substance lingers for a long time, such as fat soluble substances.

# Biology 5-8c

## Toxicology

Toxic effects – The properties of the toxic substance and the level of exposure can result in many different adverse effects on the body.

- Pulmonary toxicity – affects the respiratory system
- Cardiotoxicity – affects the heart
- Hematoxicity – affects the blood
- Hepatoxicity – affects the liver
- Nephrotoxicity – affects the kidneys
- Neurotoxicity – affects the nervous system
- Immunotoxicity – affects the immune system
- Reproductive toxicity – affects the female reproductive system
- Eye toxicity – affects the eyes

## Toxicology

**Reminder**:

Read and understand the following concepts:

- Dose-Response Relationship
- Safe Human Dose
- Legal (OSHA) Standards for Worker Safety

## Industrial Hygiene

Industrial hygiene – The science of controlling working conditions to minimize the risk of illness, injury, and death.

All employers have a legal obligation to comply with the Occupational Safety and Health Act (OSHA) to meet or exceed minimum standards for worker safety and health protection.

# Biology 

## Industrial Hygiene

Main points of the hazards to the workplace:

- Types of hazards are: chemical, physical, ergonomic, and biological.
- Toxicity becomes a hazard only when there is a possibility of exposure.
- Particles posing risks in the workplace include: silica, asbestos, lead, beryllium, coal dust, welding fumes, radioactive dust, and biological particles.
- Ventilation methods may be used to protect workers from exposure to hazardous particles.
- Noise exposure can cause hearing damage if the frequency is in the human hearing range and the amplitude is strong enough.
- Radiation can be ionizing or non-ionizing. Dealing with ionizing radiation protection requires special skills and knowledge.
- Radiation safety is managed by controlling time, distance, and shielding.
- Industrial hygiene engineering is primarily concerned with limiting worker exposure to heat and cold extremes that are health risks as opposed to comfort preferences.
- Ergonomics is the study of human characteristics to make work efficient and safe. Ergonomic design includes reducing the risk of injury from stretching, reaching, and lifting, and reducing cumulative trauma disorders.
- Biological hazards include plants, animals, their excretions and secretions, and microorganisms.

## Industrial Hygiene

Personal Protection Equipment (PPE) – Any item used by workers to reduce the risk of exposure to health or safety hazards. This includes protection against all toxic exposure paths through the use of equipment such as splash shields, gloves, respirators, chemical suits, etc.

- The type of PPE depends on the substance used and the work performed.
- Regular replacement and/or decontamination of the PPE is necessary.

# Biology

## Industrial Hygiene

PPE also includes protection from other risks besides contaminants.

- Basic injury protection
  (e.g., work gloves, safety glasses, hard hats, etc.)
- More exotic injury protection
  (e.g., safety lines, antishock suits, etc.)
- Hearing protection
- Thermal protection
- Toxic protection

## Bioprocessing

Bioprocessing – The use of biological systems (i.e., bacteria) to obtain a desired result (e.g., fermentation, waste treatment, digestion).

Read and Understand:

- How water quality is tested
- Water treatment methods and digester methods