**Module 4**

**Chapter 6 – Microbial Growth**

* Microbial growth refers to increase in \_\_\_\_\_\_\_\_\_\_, not \_\_\_\_\_\_\_\_\_\_\_\_
	+ Growing microbes means an increase in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Important to understand conditions necessary for microbial growth

**The requirements for growth**

* Physical requirements
* Chemical requirements

*Temperature*

* Microbes grow within \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ temperature range
	+ Low, high temp affect \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* **Minimum growth temp –**
* **Optimum growth temp –**
* **Maximum growth temp -**
* Microbes divided into 5 groups
	+ **Psychrophiles** –
	+ **Psychrotrophs** –
	+ **Mesophiles** –
	+ **Thermophiles** –
	+ **Hyperthermophiles** –
* Psychrophiles
	+ Can grow below \_\_\_\_ °C, optimum at \_\_\_\_ °C
	+ Usually \_\_\_\_\_\_\_\_\_\_ by temperatures above \_\_\_\_ °C
* Psychrotrophs
	+ Can grow at \_\_\_\_\_\_\_\_\_\_ °C, optimum at \_\_\_\_\_\_\_\_\_ °C
	+ Cause problems with \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, can grow \_\_\_\_\_\_\_\_\_\_\_\_\_\_
		- But grow \_\_\_\_\_\_\_ 🡪 proper \_\_\_\_\_\_\_\_\_\_\_\_ helps prevent \_\_\_\_\_\_\_\_\_
* Mesophiles
	+ Many \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ grow best at \_\_\_\_ °C
	+ Mesophiles include most common \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, food \_\_\_\_\_\_\_\_\_\_\_\_\_\_ organisms
* Thermophiles, hyperthermophiles
	+ Grow is \_\_\_\_\_\_\_\_\_, volcanic \_\_\_\_\_\_\_\_\_\_\_\_
	+ Cannot grow below \_\_\_\_ °C – usually not \_\_\_\_\_\_\_\_\_\_\_\_\_\_ problem

*pH*

* pH refers to concentration of \_\_\_\_\_\_\_\_
	+ Low pH 🡪 \_\_\_\_\_\_\_\_\_ 🡪
	+ High pH 🡪 \_\_\_\_\_\_\_\_\_ 🡪
* Most bacteria grow best near \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_ grow in acidic environments
	+ \_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_ are products of acidophiles
	+ Preserved from \_\_\_\_\_\_\_\_\_\_\_\_\_ by bacterial \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_ can grow between pH 5 and 6

*Osmotic Pressure*

* Microbes dependent on \_\_\_\_\_\_\_\_\_ to carry nutrients
	+ Microbes live in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ environments
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_ environments causes water to \_\_\_\_\_\_\_\_ cell
	+ Growth inhibited due to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Food preserved by high osmotic pressure - add \_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ tolerate high osmotic pressure
* Extreme halophiles *\_\_\_\_\_\_\_\_\_\_\_\_\_\_* high salt conditions
	+ Live in the Dead Sea, salt lakes

**Chemical Requirements**

* Carbon
	+ Structural organic molecule, \_\_\_\_\_\_\_\_\_\_\_\_ source
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ use organic carbon sources
	+ \_\_\_\_\_\_\_\_\_\_\_\_ use CO2
* Nitrogen
	+ In \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, proteins, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Most bacteria decompose \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Some bacteria use \_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_
	+ A few bacteria use \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ from atmosphere
		- Called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Sulfur
	+ In \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, thiamine, and biotin
	+ Most bacteria decompose \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Some bacteria use \_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_
* Phosphorous
	+ In \_\_\_\_\_\_\_\_\_\_, RNA, ATP, and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ \_\_\_\_\_\_\_\_\_\_ is a source of phosphorous
* Trace elements
	+ \_\_\_\_\_\_\_\_\_\_\_\_ elements required in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ amounts
	+ Usually as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Organic growth factors
	+ Organic compounds obtained \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Vitamins, amino acids, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Oxygen*

* \_\_\_\_\_\_\_\_\_\_ metabolism provides more energy than \_\_\_\_\_\_\_\_\_\_ metabolism
* BUT, Oxygen is \_\_\_\_\_\_\_\_\_\_\_ in high amounts to ALL organisms
	+ \_\_\_\_\_\_\_\_\_\_ forms of oxygen are highly reactive; \_\_\_\_\_\_\_\_\_\_\_\_\_ cell components
	+ Many metabolic pathways exist to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Singlet oxygen, 1O2- -
* Superoxide free radicals, O2-
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ enzyme neutralizes free radicals
* Peroxide anion, O22-
	+ Neutralized by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ enzymes
* Hydroxyl radicals, OH- -
* Obligate aerobes
	+ Grow where \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ occurs
	+ Have \_\_\_\_\_\_\_\_\_\_ that \_\_\_\_\_\_\_\_\_\_\_\_\_\_ O2
* Facultative anaerobes
	+ Grow \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with \_\_\_\_\_\_
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ growth via \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_
* Obligate anaerobes
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to detoxify \_\_\_\_\_\_\_\_
	+ Grow \_\_\_\_\_\_\_\_\_\_\_\_\_\_ than \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Aerotolerant anaerobes
	+ Obligate \_\_\_\_\_\_\_\_\_\_\_\_, produce \_\_\_\_\_\_\_\_\_\_ that inhibit competition from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Possess enzymes to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Microaerophiles
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_ detoxify high concentrations of \_\_\_\_\_\_\_\_\_\_

*Biofilms*

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_ that holds \_\_\_\_\_\_\_\_\_\_\_\_\_\_ of bacteria together
	+ Share \_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Sheltered from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is a \_\_\_\_\_\_\_\_\_\_ created by an extracellular polysaccharide
* Formed by *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* species in mouth
	+ Only when \_\_\_\_\_\_\_\_\_\_\_\_\_\_ is present
* Plaque allows other microbes to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Form \_\_\_\_\_\_\_\_\_\_\_\_\_\_ that lead to tooth decay, gum disease
* Biofilms often form on \_\_\_\_\_\_\_\_\_\_\_\_\_ and other tubing
* Numbers are often too low to detect
	+ Biofilm protects bacteria from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Can grow rapidly once inside body, causing \_\_\_\_\_\_\_\_\_\_ and other infections

**Growing Microbes in the Lab**

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_: \_\_\_\_\_\_\_\_\_\_ prepared for microbial \_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_: no \_\_\_\_\_\_\_\_\_\_\_ microbes
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of microbes (the \_\_\_\_\_\_\_\_\_\_\_\_\_) into sterile medium
* \_\_\_\_\_\_\_\_\_\_\_\_\_: microbes growing in/on culture medium

*Agar*

* Complex \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Used as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ for culture media in Petri plates, slants, and deeps
* Generally not \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ by microbes
* Liquefies at 100°C
* Solidifies at ~40°C

*Culture Media*

* Chemically defined media: exact chemical composition \_\_\_\_\_\_\_\_\_\_\_\_\_
* Complex media: extracts and digests of yeasts, meat, or plants
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of nutrients

*Biosafety Levels*

* BSL-1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ precautions
* BSL-2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, gloves, eye \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* BSL-3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cabinets to prevent \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* BSL-4: sealed, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pressure
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_\_\_\_\_ twice

**The Growth of Bacterial Cultures**

* Recall, microbial growth is increase in \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Bacteria reproduce by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ A single \_\_\_\_\_\_\_\_\_\_\_ splits into \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cells
* Some microbes reproduce by *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
	+ Small growth (\_\_\_\_\_\_) gets larger, and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Generation time, \_\_\_\_\_ – the time it takes for a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Essentially, time it takes for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Varies among species
	+ Can be 20 mins, can be 20 days
* Microbes can grow \_\_\_\_\_\_\_\_ in ideal conditions
	+ Eg, if g = \_\_\_\_\_\_\_\_\_\_, then:
		- 1 cell 🡪 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_ in \_\_\_\_\_ generations, \_\_\_\_\_\_\_
		- 1 cell 🡪 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_ in \_\_\_\_\_ generations, \_\_\_\_\_\_\_
* Bacterial growth plotted on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Numbers \_\_\_\_\_\_\_\_\_\_\_ for linear or arithmetic graph
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ scale increases in increments of \_\_\_\_\_\_\_\_\_
	+ 10, 100, 1,000, 10,000, etc …
* Converts rapidly increasing exponential growth from \_\_\_\_\_\_\_\_\_\_\_\_\_ line into \_\_\_\_\_\_\_\_\_\_\_\_\_ line

*Phases of growth*

* Bacteria growing in liquid have characteristic growth pattern
	+ When plotted on logarithmic graph – \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The Lag Phase
* The Log Phase
* The Stationary Phase
* The Death Phase

**Measurements of Bacterial Growth**

* Bacterial cultures are quantified by two general types of measurements
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ measurements – measure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Indirect Measurements – use \_\_\_\_\_\_\_\_\_\_\_\_\_\_ measures to determine population size

**Direct measurement of microbial growth**

*Standard Plate Counts*

* Growth microbial sample on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ Count \_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_ = 1 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Advantages
	+ Only \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ counted
	+ Obtain \_\_\_\_\_\_\_\_\_\_\_\_
* Disadvantage
	+ Takes \_\_\_\_\_\_\_\_\_\_ for colonies to form
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ intensive

*Filtration*

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is passed through \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ \_\_\_\_\_\_\_\_\_\_\_ retained on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_ is transferred to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Useful when \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of bacteria in sample \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Often used to detect bacterial contamination of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Most probable number (MPN) method*

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ tube MPN test
* \_\_\_\_\_\_\_\_\_\_\_ sample
	+ Count tubes with \_\_\_\_\_\_\_\_\_\_\_\_
* Useful when bacteria \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* But, numbers are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	+ \_\_\_\_% accurate

*Direct microscopic count*

* Numbers of microbes counted \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_ results, but …
	+ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ difficult to count
	+ \_\_\_\_\_\_\_\_\_ cells look like \_\_\_\_\_\_\_\_\_\_\_ cells
	+ Need \_\_\_\_\_\_\_\_\_\_\_\_\_\_ to count accurately

**Indirect measurement of microbial growth**

*Turbidity*

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, of a liquid culture
	+ Detected using a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Higher \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, increased \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_ method of obtaining quantity, but ….
	+ Do not obtain \_\_\_\_\_\_\_\_\_\_ - values are only meaningful when \_\_\_\_\_\_\_\_\_\_\_\_ to each other
	+ \_\_\_\_\_\_\_\_\_\_\_\_ cells contribute to \_\_\_\_\_\_\_\_\_\_ just like \_\_\_\_\_\_\_\_\_\_\_\_\_ cells

*Metabolic activity*

* Assumes \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of bacteria produces \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or metabolic product
	+ Eg, measure \_\_\_\_\_\_\_\_\_\_ build up
* Can be useful when cells \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Can be performed \_\_\_\_\_\_\_\_\_\_\_\_\_\_ without needing to \_\_\_\_\_\_\_\_\_\_\_\_\_ microbes

*Dry weight*

* Removal of microbes from growth medium, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Useful for \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_