**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 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_