NS101 LEARNING OBJECTIVES

Fall 2019

Intro Week

By the end of this week, you should be able to:

Relate the wide range of scales involved in Nature to familiar objects, and explain in his/her own words how we can investigate the module questions using the Scientific method

1. Compare the **scales** (sizes in order of magnitude) of various objects (entities), such as atoms, bacteria, humans, planets, stars, galaxies, and the Universe, expressed in scientific notation
2. Describe the procedure of **Scientific method** (hypothesis, prediction, test, observation, modify/confirm hypothesis) and distinguish science from non-science
3. Identify **International System of Units (SI) units** and convert units to and from SI units correctly
4. **Estimate** physical quantities by making **reasonable assumptions** and state the reasons for the assumptions

MODULE 2: Is antibiotic resistance a big threat to the existence of humankind?

ABR 1: Introducing the Problem of Antibiotic Resistance

By the end of this week, you should be able to:

Discuss the seriousness of the antibiotic resistance problem, interpret parameters of population growth models and calculate bacterial growth rates.

1. Name different types of **microbes** and identify **bacteria** according to **shape and cell structures**
2. Identify and discuss how sensitive bacteria **develop resistance**
3. Describe **the mechanisms of antibiotic resistance** present in antibiotic resistant bacteria
4. Discuss the **emergence of antibiotic resistance** in bacterial populations
5. Interpret simple **population growth models** and associate them with conditions for bacterial growth.
6. Generate spreadsheets to **plot the data** and solve equations to **calculate bacterial growth**.

ABR 2: How do bacteria multiply? How do they defend themselves?

By the end of this week, you should be able to:

Relate the targets of antibiotics in the bacterial cell and the antibiotic resistance mechanisms to replication, transcription and translation of information encoded in the DNA.

1. Describe basic principles of biology regulating **DNA replication**, **RNA transcription** and **protein synthesis**
2. Discuss that the unique **DNA sequence** that encodes all genetic information.
3. Discuss that the unique sequence of **protein** leads to its three dimensional shape that in turn is related to its function.
4. Define the **mutation rate** and estimate the number of **mutations** per replicative cycle.
5. Explain the **processes** leading to **mutations** in the encoded protein sequence and relate these to the development of antibiotic resistance

ABR 3: How do drugs get into bacteria?

Relate the processes of passive (diffusive) and active transport to how drugs move in and out of the bacterial cell

1. Differentiate between **active and passive transport** of antibiotics across bacterial membrane
2. Model **diffusion** of antibiotics in bacteria by a random walk process and explain to a friend the probabilistic rules of a random walk process.

3. Calculate the parameters of a **random walk** model and evaluate competition between distance moved in a single step and time necessary for a single step.
4. Discuss if diffusion is an efficient mechanism of transport on different length scales and differentiate between free diffusion and **biased diffusion**.
5. Relate microscopic and **macroscopic parameters** of diffusion.

ABR4: Structure of biomolecules & Why are they targets for antibiotics?

Relate the effect of molecular interactions on the microscopic scale diffusion of antibiotic molecules in bacteria and evaluate the stability of drug-target interaction.

1. Calculate the **average kinetic energy** of molecules at room/body temperature and use the quantity ***RT*** ($k_B T$) to evaluate whether free (unbiased, unrestricted) diffusion happens at a given temperature.
2. Using simple models calculate the **internal energy** of a molecule as the sum of all the **bonded, non-bonded interactions** and relate this to the stability of the structure using RT.
3. Discuss factors influencing interactions between molecules, e.g. **drug-target interactions**.
4. Compute the **distance range** at which molecular structures "feel" each other and compare and contrast bonded and non-bonded interactions.

ABR5: How antibiotics work – Atoms and molecules

Examine the three-dimensional structures of molecules relevant to the antibiotic resistance problem, distinguish their bond types and their interactions.

1. Relate the **electronegativities** of atoms to **polarity** of molecules
2. Identify the **bonded** and **non-bonded interactions** when presented with the molecular structure of an antibiotic or its targets.
3. Distinguish various non-bonding interactions (**hydrogen bonding**, **dipole-dipole** interactions, **van der Waals** interactions)
4. Calculate and compare the **strengths of** bonded and non-bonded **interactions** in molecular structures
5. By examining the three-dimensional structure of drug molecules, relate **bond lengths** with **bond strengths**.

ABR6: Drug and target interactions at atomic scale

Analyze at atomic scale structures of a given target site and a drug to determine if interactions would be stable, and argue if changes on the binding interface, e.g. due to point mutations, would alter the outcome on the organism scale.

1. Identify **hydrogen bonds** in the three-dimensional structure of biological molecules
2. Relate **hydrophobicity** and **hydrophilicity** to protein structures and drug-target interactions
3. Predict **drug-target binding** behavior based on shape, interactions and environment
4. Describe how mutations lead to **evolutionary changes** across microorganisms

ABR7: How evolution works

Evaluate whether antibiotic resistance is a big threat for the survival of our species based on an evolutionary biology perspective

1. Explain the **evolutionary process** of differential success of genetic variants (i.e. **natural selection**) that results in organisms becoming adapted to their environment
2. Describe the process of **evolutionary diversification** through the generation of new species
3. Explain and construct simple **phylogenetic trees** to show relatedness among species