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Developing and Implementing a Mnemonic Device for Teaching Biological Organisms in STEM Education

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Abstract: ***Developing useful STEM pedagogical strategies is a constant goal for STEM instructors at institutions of higher learning. Analysis of empirical evidence illustrating retention rates and graduation rates among college students in STEM highlights the need for approaches to improve content engagement and learning. This article presents and describes using a mnemonic device to teach students about key features of living (e. g., bacteria) and non - living (e. g., viruses) organisms. The acronym TEDDI D. SMUB can be useful for analyzing parasitic, pathogenic, and free - living organisms. TEDDI D. SMUB is an abbreviation for taxonomy, epidemiology, diseases, drugs, immunology, diagnostics, symptoms, morphology, unique features, and biology. In addition to using this approach to learn about one organism, this approach is great for comparative organismal analysis. The article also introduces individual instructional assessments (IIA) that proffer a method to reduce plagiarism and better evaluate student understanding of discipline - based laboratory skills and cognitive skills. Additional mixed methods research studies are needed to validate the efficacy of the TEDDI D. SMUB mnemonic device to improve student educational outcomes and STEM department objectives.***

Keywords: instructional; learning; biology; mnemonic; assessment

1. Introduction

Most students enrolled in an introductory biology course, whether as a biology major or non - biology major, encountered the concept of the levels of biological organization that describe all life on Earth (e. g., atoms, molecules, cells, tissues, organs, organ systems, individual, population, community, ecosystem, biosphere). This organizational scheme is useful and provides a mechanism to understand the life sciences. Biology instructors always search for and evaluate new approaches to teach complicated concepts. One beneficial method for teaching biology concepts is the use of mnemonics. Mnemonic devices are a broad class of instructional tools primarily designed to enhance the memory of terms, ideas, and processes [1]. Mnemonics have traditionally been utilized in lower grades [2] and college in various disciplines [3 - 7]. Over a long period, previous studies have documented the effectiveness of using these aids to improve confidence, grades, and applicability of complicated information [8 - 9]. Companies and marketing firms know the power of mnemonic devices to sell products to consumers. Regarding STEM educators, using mnemonic devices is a smart way to improve students' comprehension levels. Several types of helpful learning strategies include the use of acronyms, images, alliteration, acrostics, and songs. The specific type of pedagogical method used in the current article is acronym - based. Acronyms are words created by taking the first word of other words you want to remember. Acronyms are more impactful when the newly created word enhances knowledge acquisition and comprehension.

2. TEDDI D. SMUB

The mnemonic device TEDDI D. SMUB may enhance student knowledge about the diversity of living organisms. The pedagogical tool may provide a sustainable strategy for organizing information about the natural world that may produce higher examination scores. TEDDI D. SMUB stands for taxonomy, epidemiology, diseases, drugs, immunology, diagnostics, symptoms, morphology, unique features, and biology. This effective organizational learning device can be applied to any biological entity and employed in any introductory biology course and advanced biology disciplines, including microbiology, parasitology, mycology, bacteriology, and virology. The current article introduces this technique by focusing primarily on pathogenic organisms. Please note the categories described below are flexible. Descriptive information may apply to multiple category types.

Taxonomy

Taxonomy is the study of classifying organisms. Classifying involves the placement and organization of information based on specific standards and conditions. The standard taxonomic structure for biology - based organisms is domain, kingdom, phylum, class, order, family, genus, and species. Not all biological systems fall within this scheme. Virus taxonomic plans, for example, do not include domains. You can also include the common names of organisms in this category. Common nomenclature based on geographic location or other factors may not align with standard taxonomic conventions. For example, the common name for *Trichuris trichiura*, a parasitic nematode in the Phylum Nematoda and Class Enoplea, is whipworm based on its characteristic external morphology. Locating taxonomic descriptions is relatively easy given the copious amounts of online search tools that exist. Be aware that taxonomic designations often change. Apply rigorous search methods to obtain current information.

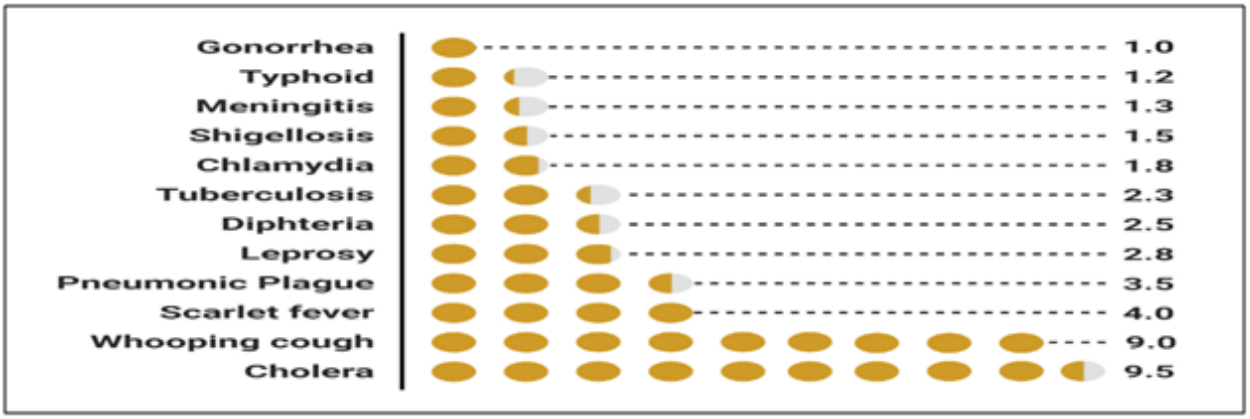

Figure 1: Reproductive number of common bacterial diseases

Epidemiology
Epidemiology is a scientific discipline focusing on disease incidence, transmission, and etiological agents. Epidemiologic data includes transmission strategies, risk factors, reproductive number (Figure 1), mortality, morbidity, incidence, geographic distribution, temporal considerations, demographics, control methods, and hospitalization frequency associated with the disease.

Diseases
Infectious diseases occur following the invasion and growth of a pathogen in or on a particular host. Present the names of the conditions that are directly or indirectly associated with your pathogen or organism. For example, *Trichinella spiralis*, a roundworm, causes Trichinellosis [10]. This section also includes surgical or medical treatment strategies to fight infection or physically remove biological organisms from the infected host. For example, surgical procedures for tapeworms involve the removal of the cestode from the infected area [11 - 12]. Medical and common terminology for diseases are also included in this section as it relates to the biological unit.

Drugs
In this section, students should research synthetic and natural therapeutics used to treat human or animal infections or diseases. Synthetic drugs are chemical treatment approaches produced using synthetic chemical processes. Most illnesses caused by biological organisms do not have a cure or vaccines. Typically, conditions that affect a large swath of the global population have resulted in the production of vaccines. For example, mRNA vaccines (e. g., Moderna and Pfizer - BioNTech) and a DNA vaccine (Johnson & Johnson) were administered to treat COVID - 19 [13 - 14]. Providing the scientific and common names of drugs is paramount in this category.

Immunology
This category includes the human and animal immune responses generated from biological infection. Innate immunity refers to host responses to any pathological threat, and adaptive immunity refers to host responses to a specific pathological type. Innate immunity quickly responds to pathogens, while adaptive immunity takes longer but displays enhanced specificity. Adaptive immunity is the last line of defense for eliminating pathogens from the human body. Figure 2 illustrates stages associated with innate and adaptive immunity. In addition to documenting host immune responses following infection, you can also record specific information regarding how the organism protects itself from internal or external threats.

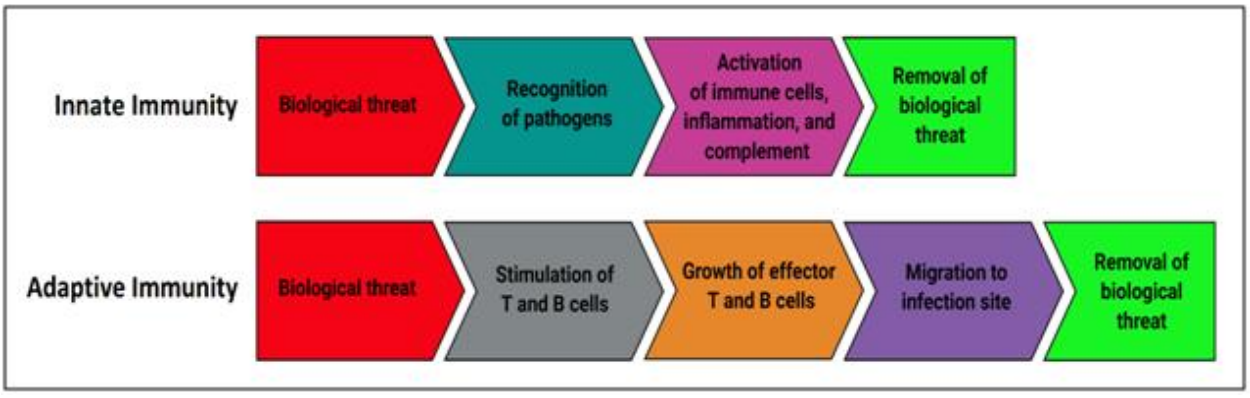

Figure 2: Features of mammalian innate and adaptive immunity

Diagnostics
Diagnostic tests refer to experimental investigations used to determine the causative agent of disease. A wide variety of diagnostic tests are employed to distinguish or identify the presence of a pathogen in or on the human body. In the case of identifying SARS - CoV - 2, a combination of molecular testing (e. g., RNA and spike protein) and serological testing (e. g., viral antibodies) is utilized [15]. Most diagnostic procedures involve some form of utilization of organism - specific molecular tests to determine the cause of disease. Each test has advantages and disadvantages as well as limitations. Automated proteomic and genomic

protocols reduce the time it takes to correctly identify the nature of infectious biological materials (e. g., organisms, components, molecules).

Symptoms

Symptoms are perceptible bodily function alterations that indicate a specific disease, physical abnormality, or microbial infection. Symptoms represent physiological disruptions that produce ostensible and measurable phenotypic characteristics. For example, human*Strongyloidesstercoralis*infection is largely asymptomatic but does involve three phases: cutaneous, pulmonary, and intestinal. The cutaneous phase encompasses localized hemorrhaging, edemas, unremitting itching, creeping eruption, and potential bacterial infection. The pulmonary stage produces damaged respiratory tissue, and the threat of pneumonia elevates. In the third phase, the intestinal phase, infected humans experience intestinal distress such as nausea, vomiting, diarrhea, dysentery, and weight loss [16]. For the most part, organisms within the same genus have similar symptoms, while some organisms in the same phylum can have quite different patterns of symptoms.

Morphology

Morphology is the science that examines the structure, shape, color, or form of biological organisms. Morphological characteristics include size, appearance, and other physical dimensions of the entire organism and analysis of the organism's internal and external molecular and structural features. Given the operational definition above, morphology can encompass an organism's phenotype and genotype. For example, it is known that SARS - CoV - 2, the virus that causes COVID - 19, is a spherical RNA virus that is approximately 120nm - 180nm. The learning aid described in this article will help build knowledge of the organism and help learners differentiate organisms; thus, providing more morphological details for organisms within the same genus may be beneficial.

Unique Features

Document novel, unusual, or interesting organismal information in this category. Some living organisms have uncommon characteristics that may separate them from other lifeforms in the same taxonomic group. Some living organisms have unique structural features, functional cells, tissues, or amino acid sequences. Locate special features by perusing current research literature or textbooks. Here you place specific information about the organism of interest that does not necessarily fit in the other categories (e. g., genome size, variants, unconventional enzymes).

Biology

This section of the instructional system refers to precise information about your biological organism's reproduction or replication process. Biology also refers to specific information about the infection process or life cycle associated with your organism of interest (e. g., How does *Listeria* infect the host?) (Figure 3). Some organisms pass through a free - living stage and a parasitic stage. Further, some organisms contain one or multiple intermediate and definitive hosts during their lifecycle. This section is different from the epidemiology section that explores transmission strategies. Here students are instructed to understand the specific and essential molecular and cellular interactions that facilitate disease; for example, *Paragonimuswestermani* utilizes at least two intermediate hosts and a definitive host and requires lifecycle stages that require aquatic environments for organismal transition into different phases of development [17]. Moreover, unlike the epidemiology section, this section is not concerned with statistical information that describes transmission rates or geographic distribution of a particular pathogen.

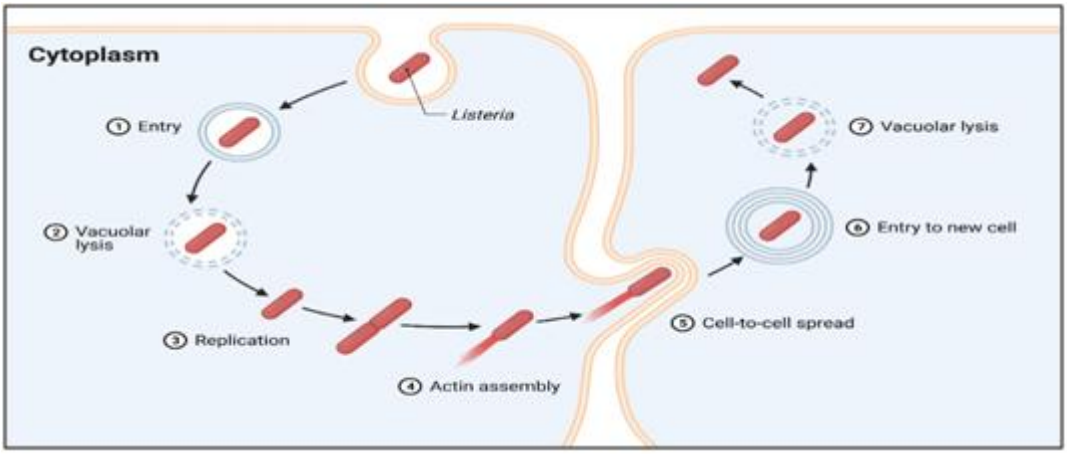

Figure 3 Intracellular lifecycle of *Listeria* in a host cell

3. Individual Instructional Assessments

The pedagogical approach described in this article allows biology instructors to create individual instructional assessments (IIA). In a future publication, the author will provide details of IIA, explain why IIA are important, and show examples of IIA. In general, IIA are assignments that instructors can use to ensure that each student engages in a unique and specific task that leads to measurable gains in comprehension and applicability. Too often, biology instructors assign the same instructional activity to the entire class. In addition to lacking creativity, this may encourage plagiarism and apathy toward the course. Specifically, an instructor could task each student with conducting a TEDDI D. SMUB investigation using the literature and assign each student a different organism. Thus, while the assignment

instructions would be the same for each student, each student would have to identify and utilize various literary resources to complete the individualized assignment. A detailed rubric that provides clear guidance regarding assignment evaluation and expectations is mandatory for individual instructional assessments. In the case of TEDDI D. SMUB, instructors can assign either individuals or separate groups to locate information. Students can either present information orally or using written documents.

4. Conclusion

Instructors from all grade levels and subjects continuously seek to identify effective instructional strategies to help students learn critical content. Mnemonic devices represent diverse research - based methods that allow students to remember course material. Biology instructors are encouraged to develop new ways to infuse various mnemonic devices to support student learning. This article describes using an acronym (TEDDI D. SMUB) as an instructional tool to establish a general and comparative understanding of biological units. Future empirical studies will explore how TEDDI D. SMUB and individual instructional assessments improve grades, learning, and self - efficacy.

Acknowledgements
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