

SOURCE Lesson Plans Detail

The RNA World

Topic	Central Dogma/RNA
Program	Brown Science Prep
Developed by	Michael Danziger and Harry Wanar
Developer Type	Undergraduate students

Overview / Purpose / Essential Questions

What is the Central Dogma?

What role did RNA have in the origin of life?

Performance / Lesson Objective(s)

Explain the processes of replication, transcription, and translation, along with the major molecules involved

Discuss theories on the molecular origin of life

Lesson Materials

NYT article

http://www.nytimes.com/2011/07/28/science/28life.html?_r=1&sudsredirect=true

Water, sugar, yeast, test tubes, balloons

Lesson Motivation

To offer various theories on the origin of life, and ask students which theory is the most scientifically plausible

Lesson Activities

1. Introduction to Molecular Biology

A. What is molecular biology?

1. The study of the molecular basis of central dogma processes (replication, transcription, translation)

B. Central Dogma

1. DNA is the master controller
2. mRNA is transcribed from DNA
3. mRNA is translated at the ribosome into protein

C. What molecules are involved in molecular biology?

1. DNA
 - a. Four nucleotides: adenine, thymine, cytosine, guanine make polymer
 - b. double helix of complementary strands (chargaff's rules)

2. RNA

a. mRNA, tRNA, rRNA

- i. mRNA: messenger RNA - transcribes genetics info from DNA, brings it outside nucleus
- ii. tRNA: transfer RNA - links individual amino acids to three letter sequences (codons) on mRNA
- iii. rRNA: Ribosomal RNA - forms active site of ribosome (protein/rRNA complex that catalyzes peptide bond formation)

3. Polypeptides

a. Proteins

b. Enzymes – important to stress that all enzymes are proteins but not vice versa

- i. question: If certain proteins are required for translation (ribosomes), then how are those proteins themselves translated? (chicken and egg)

2. DNA vs. RNA

A. Functional differences

- 1. In RNA, thymine is replaced with uracil
- 2. RNA is commonly found in single-stranded configurations
- 3. RNA is not static – it moves around and does stuff (goes outside of nucleus)
- 4. RNA is catalytic – what does this mean?
 - a. Certain RNAs can act like enzymes, creating and/or cleaving bonds
 - i. Ribozymes
 - ii. The Ribosome
 - iii. Spiegelman monster

? Short strand of RNA that replicates itself in the presence of an RNA-directed RNA polymerase (a hint at what is to come)

3. Abiogenesis and the RNA World Hypothesis

A. RNA Viruses

- 1. RNA from virus inserts itself into host cell, reverse transcriptase turns RNA into DNA, cell replicates, spreading virulent DNA
 - a. RT has no proofreading mechanism, making it extremely error-prone
- 2. Thought to be exceptionally old (Ebola, Marburg, retroviruses, etc)
- 3. 8% of the human genome is composed of HERVS – Human Endogenous Retroviral Sequencers
 - a. Must have accumulated over the course of thousands of years
- 4. RNA viruses have reverse transcriptase, which converts their RNA genomes into DNA
 - a. RT has no proofreading mechanism, making it extremely error-prone

B. Abiogenesis

1. The study of how cellular life arose from molecules
2. How?
 - a. Evolution?
 - b. Panspermia?
 - c. Other?
3. Hoyle's Fallacy – junkyard tornado
 - a. "The chance that higher life forms might have emerged in this way is comparable to the chance that a tornado sweeping through a junkyard might assemble a Boeing 747 from the materials therein".
 - b. Problem is, the species did evolve the way it did, so the probability that the species *would* evolve = 1 because it exists
 - i. Differently put, regardless of the random molecular events necessary to generate cellular life, it had to evolve the way it did because we exist (this just connects everything to the idea of molecular evolution)

C. The RNA World Hypothesis

1. Posits that:
 - a. Once nucleotides were formed, they were polymerized into RNA
 - b. Randomly, ribozymes (RNA molecules that act as enzymes) capable of self-replication would have formed
 - i. The more error-prone RNA molecules were more likely to evolve (more chances for favorable mutations)
 - c. Selection pressures would have resulted in ribosomes in order to form polypeptides
 - d. Polypeptides outcompeted ribozymes for catalytic efficiency, which is why nucleic acid is now relegated to information storage (dovetails to the notion of RNA viruses being really old)
2. Why does RNA make sense as the first hereditary molecule?
 - a. It's (auto)catalytic, so in an early environment in which there was only RNA, it would be able to replicate itself
 - b. It's biochemically extremely similar to DNA, but less reliable as a storage molecule
 - i. This implies that the evolution from RNA to DNA makes sense – as cellular life evolved, DNA became the favored storage molecule, while RNA performed as it did in the RNA world: synthesizing proteins in the ribosome from an RNA transcript
 - c. RNA replication is extremely error-prone.
 - i. In early evolution, the point was to get all sorts of errors that would further evolution (natural selection, y'all)

Support for RNA world hypothesis

http://www.nytimes.com/2011/07/28/science/28life.html?_r=1&sudsredirect=true

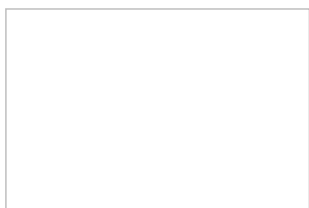
- go over article with students

- Does self-replicating RNA qualify as something that is "alive"? What are the requirements for life?

Experiment: Is yeast alive? (seperate attatchment)

Procedure

Is Yeast Alive?



- We've all seen yeast in our everyday lives – water, flour, yeast, and sugar make up a (simple) bread dough, which gets baked into a loaf.
- We know that water, flour, and sugar are not alive, but what about yeast? How could we test to see if it is alive?
- One characteristic of a living organism is metabolism (the ability to take “food” and convert it into energy, along with some byproducts)
- To find out, we'll give the yeast food (sugar), and see if it is able to break it down into carbon dioxide and water
 - o Sugar + Oxygen → Water + Carbon Dioxide (cellular respiration)

THE SCIENTIFIC METHOD

Question: Is Yeast Alive?, or Is yeast capable of metabolizing sugar?

Hypothesis. Either:

Yeast IS capable of metabolizing sugar (yeast is alive)

OR Yeast IS NOT capable of metabolizing sugar (yeast is not alive)

Test: Feed yeast sugar. Watch to see if products are formed

(which product will be easier to observe? How will we observe it?)

Analysis: What happened during the test?

Conclusion: Is your hypothesis true or false?

Materials:

- Yeast

- Water
- Sugar
- Test tubes/test tube rack
- Balloons

Experimentation:

- An important idea in setting up your experiment is the control group
- That is, we want to make sure that if gas forms when sugar is added to yeast, gas doesn't form when yeast is just by itself (we want to know that the gas formation is caused by the addition of sugar)

Procedure

1. Set up two sets of test tubes: One set will contain water, sugar, and yeast, and the other set will contain just water and yeast
 - a. Note: the number of tubes per set will depend on number of students/availability of materials
2. Fill each tube about $\frac{1}{4}$ with warm water. Add about $\frac{1}{4}$ of a packet of yeast to each test tube
3. Shake well
4. To the tubes in the first set: add about $\frac{1}{2}$ a packet of sugar to each test tube
5. Fill all tubes with water to about the $\frac{3}{4}$ line
6. Cover all the tubes with balloons. Observe gas formation over the next 30 minutes

Analysis

- Which balloons inflated? Which didn't?
- What caused the balloons to inflate? (hint: see chemical equation above)
- If gas is being released, what is happening with the sugar and the yeast?
- Is the yeast alive?

Wrap up / Conclusion

Ask students whether they believe the yeast is alive or not

Follow up

quiz students on basic central dogma processes

Supporting Web Information

http://www.nytimes.com/2011/07/28/science/28life.html?_r=3&sudsredirect=true

Reference(s)

<http://cshperspectives.cshlp.org/content/early/2010/07/06/cshperspect.a003681.full.pdf>

Pre Assessment Plan

Ask students what they know about the origin of life

Post Assessment Plan

Ask students, in light of lesson, how they think life arose

Supplies List

QTY	UNIT	ITEM
4	Each	1.5 ml tubes
4	Package	Sugar
4	Package	Yeast
4	Each	Balloons

Alignment Info

Audience(s)	High school students
STEM Area(s)	Biology
Standard(s)	<i>Life Sciences (RI GSE) LS1.9–11.1a</i> Students demonstrate understanding of structure and function–survival requirements by... explaining the relationships between and amongst the specialized structures of the cell and their functions (e.g. transport of materials, energy transfer, protein building, waste disposal, information feedback, and even movement). <i>Life Sciences (RI GSE) LS1.9–11.2a</i> Students demonstrate an understanding of the molecular basis for heredity by ... describing the DNA structure and relating the DNA sequence to the genetic code. <i>Life Sciences (RI GSE) LS1.9–11.2b</i> Students demonstrate an understanding of the molecular basis for heredity by ... explaining how DNA may be altered and how this affects genes/heredity (e.g. substitution, insertion, or deletion). <i>Life Sciences (RI GSE) LS1.9–11.2c</i> Students demonstrate an understanding of the molecular basis for heredity by ... describing how DNA contains the code for the production of specific proteins.
Activity Type(s)	Lecture Hands-on
Grade Level(s)	High School
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