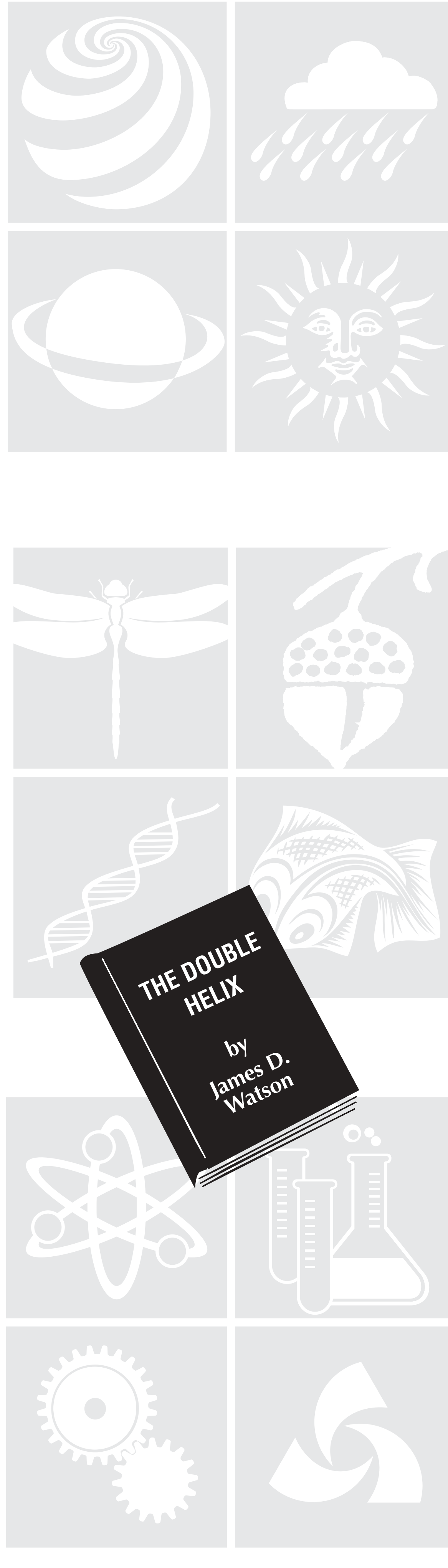
Grades

9-12

Strategic Science Teaching



Title of Lesson:

Double Helix

Essential Question:

What is the chemistry of heredity?

Conceptual Statement:

DNA is a very large biochemical molecule. Its chemical structure enables DNA to carry out the heredity function of accurately passing information from generation to generation.

Conceptual Learning Sequence:

This lesson would serve as an introductory lesson in a unit exploring the chemistry of living things.

Student Outcomes:

- Students describe the chemical structure of the DNA molecule.
- Students build a model of the DNA molecule based on available information, and appreciate the advantages and limitations of models.
- Students use "LINK" to extract information from text about DNA and its discovery.

Lesson Overview:

In this lesson students learn the context for the discovery of the DNA molecule by jigsawing the opening chapters of The Double Helix. Students use "LINK" (List, Inquire, Note and Know) to access their prior knowledge about this context and to prepare for the reading. Students build several models of DNA, refining the models as they receive more information. Students read a section in The Double Helix to better understand how interpretations of data led to the discovery of the structure of DNA. They apply their understanding of the structure by building a model that incorporates information from the text and from their previous models.

English Language Learning:

English Language Development standards are referenced in the lesson where appropriate. The hand icon appears throughout the lesson when learning strategies and lesson components are identified as pathways for academic success and reflect critical developmental differences for students who are English learners.

Literature in the Science Learning Cycle:

Several selections from The Double Helix are used in the ENGAGE stage to assist students in understanding the context (people/places) of the scientific work that surrounded the discovery of DNA's structure. In the EXPLAIN stage, students use a reading from the book to gather information about the structure of DNA, compare the information to their models, and understand the complexities of scientific discovery.

Learning Strategy:

This lesson uses "LINK" which prompts students to brainstorm what they will encounter in a reading selection, and to direct their discussion of what they already know about a topic. (See Appendix pages 186-187.)

Literature Selection:

Title: The Double Helix
Author: Watson, James D.
Publisher: Mentor Books, 1968 ISBN: 0451627873
Annotation: James Watson, Francis Crick and Maurice Wilkins were awarded the Nobel Prize in 1962 for determining the molecular structure of DNA. This book is the personal story of Watson's involvement with the discovery and documents both his interpersonal and scientific thinking. The book provides a behind-the-scenes look at the very human side of scientific discovery.
Genre: Narrative Nonfiction

Grades 9-12

California Content Standards:*

Science Standard: Grades 9-12
Organic Chemistry and Biochemistry

10. The bonding characteristics of carbon allow the formation of many different organic molecules of varied sizes, shapes, and chemical properties and provide the biochemical basis of life. As a basis of understanding this concept:
    a. Students know large molecules (polymers) such as proteins, nucleic acids, and starch, are formed by repetitive combinations of simple subunits.
    e. Students know how to identify the functional groups that form the basis of alcohols, ketones, ethers, amines, esters, aldehydes, and organic acids.

Biology/Life Science: Grades 9-12
Genetics

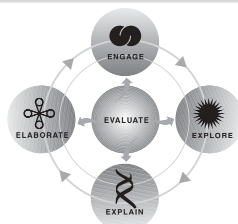
5. The genetic composition of cells can be altered by incorporation of exogenous DNA into the cells. As a basis for understanding this concept:
    a. Students know the general structures and functions of DNA, RNA, and protein.

1. Investigation and Experimentation
Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other four strands, students should develop their own questions and perform investigations. Students will:

d. Formulate explanations by using logic and evidence.
g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.
k. Recognize the cumulative nature of scientific evidence.
l. Analyze situations and solve problems that require combining and applying concepts from more than one area of science.

*Specific standards addressed in this lesson.

Lesson at a Glance

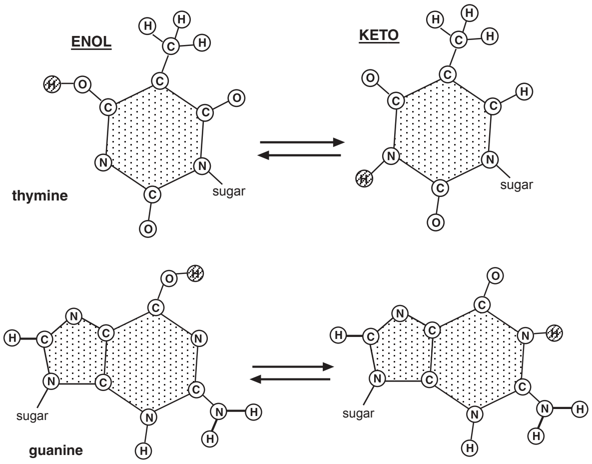


Science Learning Cycle	Objective Learning Strategy, Science Process	Suggested Time
ENGAGE	Students use “LINK” to make a conceptual map about the context surrounding the discovery of DNA. They engage with the text to complete this concept map. Communicating	50 minutes
EXPLORE	Through a series of activities, students explore how to use information to build and refine models. Students recognize the strengths and limitations of models to understand phenomena. Communicating, Infering, Observing, Ordering	50-100 minutes
EXPLAIN	Students read a selection from The Double Helix to help them explain the structure of DNA. Using information from the book and their models from the EXPLORE stage, students refine their models to account for DNA’s functions. Communicating, Comparing, Inferring	50 minutes
ELABORATE	Students demonstrate and extend their understanding of the structure of DNA by building a paper model of DNA that reflects certain criteria. This stage incorporates the EVALUATE stage. Communicating, Comparing, Inferring, Applying	50 minutes
EVALUATE	Students evaluate their understanding by constructing a paper model of DNA in the ELABORATE state. Teacher evaluates student understanding of student outcomes in this activity as well throughout the lesson. Applying	Part of the ELABORATE stage

Double Helix

Teacher Background:

Scientists knew that DNA was the molecule that enabled heredity, but it was not clear if the science of the day could reveal the structure of a molecule a million times bigger than a water molecule. The research evidence about its chemical makeup and structure was in a messy stage. Rosalind Franklin's new X-rays of DNA crystals indicated a helical structure, but even she had strong doubts about that conclusion. Chargaff had evidence that the number of adenines roughly equaled the number of thymidines (A=T) and that guanines also equaled cytosines (G=C). Nobody knew what this meant, or even whether it was true or important. The repeating phosphate-sugar backbone could be placed on the outside or the inside of the structure.



Watson and Crick combined model-building with the X-ray data and the chemistry of the bases to eventually find the solution. When Watson used the keto instead of the enol structures of the bases, he found that the hydrogen bonded A+T base pairs have the exact same shape as the hydrogen bonded G+C base pairs. Enol and keto are two different ways that the same atoms can bond with each other. The differences in hydrogen position and oxygen bonding result in very different patterns of hydrogen bonding.

Watson's model-building showed that the atoms would fit properly only if the sugar phosphate backbone was on the outside. His "like-with-like" model did not work because the bigger purine-purine base pairs take up more space than the smaller pyrimidine-pyrimidine base pairs (especially using the keto forms). In contrast, the A-T and G-C base pairs (both being purine-pyrimidine combinations) have exactly the same size and shape, so they can fit uniformly within the sugar-phosphate backbone.

Note a possible teacher/student misconception: The book emphasizes the nucleotide bases. Yet, DNA is an acid. DNA has both acidic groups (the phosphate backbone) and basic groups (the nucleotide bases). The acidic groups are stronger, so over-all it is an acid.

Related Standards:

English-Language Arts: 9th and 10th Grade

Reading Comprehension (Focus on Informational Materials)

Students read and understand grade-level-appropriate material. They analyze the organizational patterns, arguments, and positions advanced.

Comprehension and Analysis of Grade-Level-Appropriate Text

2.5 Extend ideas presented in primary or secondary sources through original analysis, evaluation, and elaboration.

Reading: 11th and 12 Grade

Comprehension and Analysis of Grade-Level-Appropriate Text

2.4. Make warranted and reasonable assertions about the author's arguments by using elements of the text to defend and clarify interpretations.

English Language Development Standards

9-12 Reading Comprehension

Recognize a few specific facts in familiar expository texts such as consumer and workplace documents and content area texts.

Read and orally identify a few specific facts in simple expository text such as consumer and workplace documents and content area texts.

Orally identify main ideas and some details of familiar literature and informational materials/public documents (e.g., newspapers, brochures, etc.) using key words or phrases.

Apply knowledge of language to achieve meaning/comprehension from informational materials, literary texts, and texts in content areas.

Grouping:

Whole group, groups of 4, individual

For hands-on activities, mix the EL with the native speakers. For debriefing, include at least two EL with native speakers to form discussion groups.

Materials:

Per Class
Video- *Race for the Double Helix* (optional)

Per Group
45 Pop-it beads or paper clips of 4 different colors (e.g., red, green, black and white)
Assortment of fastening materials (e.g., twist ties, wire, rubber bands, yarn/string)
8 Copies of Student Page 2.0
Scissors
Scotch tape, Masking tape

Per Student
Tray with rim (e.g., Styrofoam meat tray)
Model #1, #2, and #3 cards from Student Page 1.0
Student page 2.0
Colored pencils (optional)
The Double Helix

Advance Preparation:

1. Duplicate enough Student Page 1.0 for each student. Cut the model cards apart.
2. Assemble pictures or realia of a zipper, spiral staircase, slinky, and double helix.
3. Using card stock, duplicate 8 copies of Student Page 2.0 for each group.

Teacher Resources:

Race for the Double Helix video, Salk Institute, La Jolla, CA 18 minutes, 1992.

Teacher Tips:

- If pop-it beads are not available, or if you think your students will not respond favorably to their use, use paper clips instead.
- For durability, laminate the model cards.
- Models 1-3 are exploratory; as students begin to make their models watch for patterns in the way they set up the pop-it beads or paper clips. These patterns provide evidence of student understanding.
- Remind students to build their models based on the information given to them.
- If you think students need more familiarity with the puzzle pieces (names and shapes), have students color the individual piece to indicate what they are.
- Provide two colors of tape so that students can indicate hydrogen and covalent bonding on their paper model.
- Open the ELABORATE/EVALUATE stage by having students design their own paper model rather than using Student Page 2.0
- Use the book to help students understand that interpersonal competitions and conflicts are often part of a scientific endeavor. The examples in the book provide fodder for rich discussions.

Related Student Resources:

Access Excellence http://www.accessexcellence.org/RC/index.html#students

Asimov, Isaac. *El Codigno Genetico*, 1986

Human Genome Project http://www.nhgri.nih.gov/HGP

Molecular Biology On-Line http://www.iacr.bbsrc.ac.uk/notebook/courses/guide/dnast.htm

Lesson Credits:

Adapted from Biological Science Curriculum Studies, Biology, A Human Approach, Chapter 12.

VOCABULARY

amino acids – organic acids with the amino group NH_2; the main components of proteins

covalent bonding – strong chemical bonds that connect atoms; in DNA, the bonding within a strand (e.g., sugar-phosphate bond)

DNA – deoxyribonucleic acid, a nucleic acid formed from a repetition of simple building blocks called nucleotides

gene – a specific sequence of nucleotides in DNA or RNA

helix – a spiral or coiled shape; the shape of the DNA molecule

hydrogen bonding – the type of weak bonding between strands of DNA (e.g., between adenine and thymine)

nucleotides – base constituents of all genes (adenine, cytosine, guanine, and thymine)

The Science Learning Cycle:

Double Helix

ENGAGE:

1. Use “LINK”(List, Inquire, Note, Know) to prepare the students to read the first selection in *The Double Helix*. Create a concept map on the board with the words “Discovery of DNA” in a center circle; make three circles from this center circle and label one “people”, another “places,” another “type of research.” Ask students to list, on their own paper, words that they associate with any of the circle concepts.

2. Ask several students to share their ideas and chart them in appropriate places on the concept map. In small groups, ask students to share and elaborate on the ideas on the board and on their own list.

3. Show *The Double Helix* book cover to the class. Based on their conversations in Step 1 and 2, ask students to write a statement about the concepts that they might find in this reading. This step is optional.

4. Divide the class into groups of three; have student count-off 1, 2 or 3. Ask all number 1’s to read chapter one; number 2’s to read chapter 2, and number 3’s to read the first four paragraphs of chapter 3.

5. After the students have completed their reading, ask student to identify some of the major characters (e.g., James Watson, Francis Crick, Maurice Wilkins, Rosalind Franklin, Linus Pauling, Sir Lawrence Bragg), where they worked (e.g., Cambridge, Cal Tech), and how they contributed to the field knowledge about DNA (e.g., X-ray diffraction; genes composed of DNA; work on proteins; work on viruses). Add their information to the class concept map.

EXPLORE:

6. Briefly summarize that while there were many people doing research at the time, and much data had been gathered, it remained unclear just what DNA looked like. The scientists were involved in using pieces of information, gathered from several places, to make models that might be the structure of DNA. To them, “DNA was the most golden of all molecules.”

7. Ask students to imagine themselves as part of a team of research scientists involved in an effort to describe the DNA structure. Explain that their task is to build a model based on available information, and to then change the model, as new information becomes available.

8. Distribute a Model #1 Card to each student, and the materials to groups of four students. Explain that although they will work as team, each student will build their own model to compare with other students. Provide time for students to build the model, then ask them to share with each other.

9. Ask students to analyze their model. What features represent the properties of DNA as described on the Model #1 card? How might this structure allow DNA to store information, in general, and to store different information along its length? If necessary, prompt the discussion by asking why they placed the colored beads (paper clips) in the order they did.

10. Distribute a Model #2 Card to each student, and ask students to modify their original model based on the information on this card. Provide time for students to build the model, and then ask them to share with each other.

11. Help students critique the usefulness of their model in representing the “clues” from the Model #1 Card and the Model #2 Card. If there is no modeling of the bonding between the strands, ask what materials the students might use to indicate the weak hydrogen bonds (fasteners). Note: base complementarity is not necessary at this point.

12. Display a picture or realia of a zipper, spiral staircase, slinky, and double helix. Have students compare the structure of their DNA model with these items. Remind students that models are useful, but that they do not portray all the nuances of the real thing!

13. Distribute a Model #3 Card to each student and ask students to modify their original model based on the information on this card. Provide time for students to build the model, and then ask them to share with each other.

14. Ask students: “What is the relationship between subunits bonded to each other on opposite strands of the DNA double helix?” (depending on their model, it will be “like-to-like” or two different colors always opposite each other).

The Science Learning Cycle: **Double Helix**

EXPLAIN:

15. Ask students to use "LINK" to prepare for their next reading. Have them List what they know about the DNA molecule to this point. Ask them to Inquire of each other what the other person knows.

16. Ask students to read Chapter 25 and 26 and the illustration in Chapter 27 in *The Double Helix*. Write these questions on the board and ask students to answer them (take Notes) from information in the reading:
• What are the subunits of DNA?
• What is Chargaff's rule?
• What does the diameter of the DNA model have to do with its structure?
• How did choosing the keto instead of the enol forms of the bases contribute to the model?
• What are the interactions between the subunits on each strand?
• How does the sequence of subunits on one strand provide a template for the sequence of the subunits on the other strand?

17. Ask students to share what they know about the structure of DNA from their reading.

ELABORATE/EVALUATE:

18. Have students discuss how they would modify their third model based on the information they learned from the reading. How does the structure reflect the functions of information storage and transmission of genetic material?

19. Divide students in groups of four. Provide 8 copies of Student Page 2.0 to each group. Ask them to synthesize their understanding about the structure of DNA by constructing, as a group, one paper model. Ask students to use the two types of tape to denote covalent and hydrogen bonding. Note: as an alternative, have students design their own paper model template. In either case, critique their model for the following:
• sugar-phosphate "backbone"
• two strands with 12 base-pairs
• identified bases: adenine, thymine, guanine, cytosine
• purines (adenine, guanine) are the large base pieces; pyrimidines (thymine, cytosine) are the small base pieces
• complementarity of bases
• recognition that the diameter of the molecule should be the same
• double helix structure
• identification of hydrogen bonding between strands
• identification of covalent bonding within strands

20. Students submit a definition of the chemical structure of DNA that is a refinement of their original "LINK" definition.

Teacher Reflection:

1. How does the student work provide evidence that they understand the structure of DNA, and appreciate the advantages and limitations of models?
2. What instructional strategies used in this lesson promote student understanding? How do you know?
3. How does the literature selection support student understanding of the science concepts?
4. How would you modify instruction to ensure understanding of student outcomes by all students?

Model #1 Card

Observations about the Structure of DNA

✓ DNA is a polymer: a very long, chainlike molecule composed of small subunit molecules. Covalent bonds attach the subunits, like links on a chain.

✓ Four different types of subunit molecules exist.

Model #2 Card

Observations about the Structure of DNA

✓ DNA has two long chains of subunits twisted around each other to form a double helix.

✓ The two helical chains (strands) are bonded together weakly, with subunits on one strand bonding to subunits on the other strand

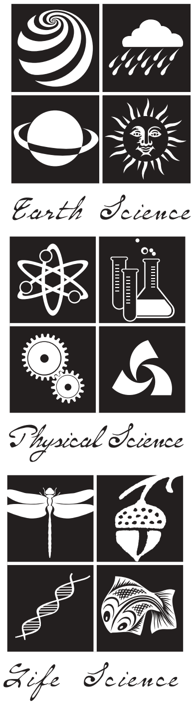
✓ The diameter of the DNA molecule is uniform along its length.

Model #3 Card

Observations about the Structure of DNA

✓ The order of subunits in one strand of DNA determines the order of subnunits in the other strand.

✓ As you try to solve this portion of the model, consider that the aspect of DNA's structure that you now are modeling provides clues for the patterns of DNA replication.



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Through the leadership of the California County Superintendents Educational Services Associations science committee, you have an opportunity to purchase the June, 2002 publication "Strategic Science Teaching, Grades K-12: A Sampler of Science Lessons Connecting Literature with the California Standards." This publication features science lessons at each grade level, K-12, including:

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