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# Assessing TMDL Implementation in the Macatawa Watershed, MI, Using Swat

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# DOES ACCESS TO A MANIPULATIVE MODEL ASSIST STUDENT LEARNING OF DNA PROCESSES?

by

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# DOES ACCESS TO A MANIPULATIVE MODEL ASSIST STUDENT LEARNING OF DNA PROCESSES?

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In my nine years of teaching experience I have seen students struggle with understanding DNA, RNA, replication, transcription and translation. I wanted to know if students used the same model that I designed throughout a unit that covers the concepts of DNA and the processes if they would gain a better understanding. To test this idea I created a manipulative of puzzle pieces along with inquiry type lessons that includes DNA and RNA nucleotides, tRNA, a ribosome, amino acids, nitrogen bases for the tRNA and peptide bonds. Two teachers were involved and each taught a control group and an experimental group. The experimental group learned by using the new model with its accompanying lessons along with other assignments while the control group learned by lectures, a couple of different models and other assignments. The students took a pre-test before the unit and the same test as a post-test after the unit. The gain score was determined and studied using ANOVA techniques.

After comparing the gain scores for the two groups there was no significant difference between them although the experimental groups did have a slightly higher gain score. This would imply that there is a slight benefit and that with more research and adjustments to the model there may be more benefit that would be significantly different.

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Finally and most importantly, I would like to thank my family. I would not have been able to accomplish what I have without their support. Their understanding and love is what has allowed me to finish this project.

Patricia A. Richardson

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## I. PROBLEMS AND IMPORTANCE

### Problems in Science Education

There has been much research done on student learning. Much of this has been on what students' prior conceptions are and how they affect student learning. Whenever a student encounters new phenomena they rely on their current concepts to organize what they are learning along with forming questions, recognizing answers, and distinguishing relevant information from irrelevant (Posner, Strike, Hewson & Gertzog 1982). Even if students do not have immediate information related to what they are learning they will use the skills they have and their prior knowledge to help decipher the new concepts. All learning involves the interpretation of the given situation, whether it is in the classroom or outside, through the perspective of the students' existing knowledge (Smith, diSessa, & Roschelle, 1993).

Research suggests that taking into account students' prior knowledge is one important way to improve student learning. This can be done formally or informally. This prior knowledge can be formed by interactions in the classroom or with the physical and social world (Smith, diSessa, & Roschelle, 1993). With regard to DNA, much of the prior knowledge is formed from what students hear and read in the media. In my observations while teaching for instance, court cases and crime drama shows make up the bulk of the media coverage, leading to a widespread perception that DNA only relates to blood. Students use this prior knowledge to help them make sense of what they are

learning. A student needs to recognize that what they currently know or think about a concept is not complete enough to serve them well for scientific thinking. This is difficult to accomplish because the students' concepts have been serving them just fine for most of their life. "Learning is a process of finding ideas that sensibly and consistently explain some problematic aspect of the learner's world" (Smith, diSessa, & Roschelle, 1993). As such, teachers must provide students reasons to change their thinking about the world.

How students perceive the topic to be taught affects the students' ability and willingness to learn it (Johnstone & Mahmoud, 1980). As such, teachers must help students see relevance in their lives for learning a new topic. If teachers attempt to make the topic relevant and understandable at the students' level they may be more willing to learn. Many students in high school are still functioning at the concrete level and therefore their learning is limited to experiences they can see and manipulate making abstract topics harder for them to learn (Malacinski & Zell, 1996). This is where models can be helpful for increasing student understanding of abstract concepts such as DNA and its processes.

**Problems in Teaching Biology**

Teachers need to understand what students know about the topic being taught, how students learn science and which learning strategies are best for conceptual development (Wandersee, Mintzes & Novak, 1994). There has been plenty of research done on this, and biology is no exception. In examining students' misconceptions in

introductory college biology courses, most of the concepts students hold are poorly defined and/or hard to differentiate from other kinds of errors (Fisher & Lipson, 1982). Students have a wide range of conceptions that are hard to define since they are vague. For example when I have asked students about what they know of DNA I'll hear "blood", "genes", "what?", "Jurassic Park", and "cells" to name a few. This is in contrast to some of the conceptions students hold in Physics, which may be very specific and strongly held but not necessarily accurate. The strength and depth of the prior knowledge has a profound effect on how teachers help students correct and build off of their prior conceptions.

Learning about DNA is inherently problematic in this regard. Students are not able to directly see cells, DNA, photosynthesis etc. They experience the world around them but do not think about the microscopic or macroscopic processes that are occurring. For instance, they push objects or experience movement all the time and so have formed more deep-seated concepts about these experiential type concepts prior to learning the science behind them. The same cannot be said for less formed conceptions, which are less deeply seated. The less deep-seated concepts are held the more likely students will be able to change or give up their prior concepts (Fisher & Lipson, 1982). Deep-seated concepts are ones that have been reinforced and seen as reasonable for a long period of time. They have been used by students often and seen as the best explanation for the concept at hand and seems to work for the situations they have been presented with. Less

deeply held concepts are those that students have not used often or thought a lot about so they are not held as closely and are therefore easier to accommodate towards a scientific thinking. Biology, like physics, has both deep-seated and less deeply held concepts.

Errors in management of knowledge are common in biology since the students' must learn many new terms and concepts that are all inter-related by structure and function (Fisher & Lipson, 1982). This is common across many biology content areas. Students must be able to link what they are learning with what they have already learned for true conceptual learning. Instead, students often memorize but do not understand the meaning of what they have learned (Fisher & Lipson, 1982). This makes it progressively harder for students to understand each following concept because of how inter-related they are.

Students' depth of understanding is shown by their ability to generate new material or solve new problems (Fisher & Lipson, 1982). This should be the ultimate goal in teaching since we are trying to create scientifically literate students. For students to apply what they have learned in school to the world they live in, students' must have a deep understanding of how the world works. Biology has been more and more prominent in the media and politics making it more important for students to gain a deeper understanding and not just memorize terms.

DNA and the processes of replication, transcription and translation are part of the biology curriculum at the high school level. It is necessary for students to have a basic and deep understanding of these concepts to make sense of how genes work. The

National Science Education Standards for grades 9-12 include

> "(1) In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular letters and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome.
> (2) Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organisms offspring." (page 185)

**Problems with DNA Unit**

I have taught DNA as one unit of instruction for eight years and have seen students struggle with DNA concepts and processes. Students need a way to internalize these concepts to have a deeper understanding. DNA has been taught both before teaching a unit on genetics and after. It would seem that the big picture would be easier to see if DNA was studied before genetics, as it should lessen the misconception that genes are actually the letters that are used in Punnett squares. Genetics and DNA are closely related topics. Students need to conceptualize both of these concepts.
Several different models to teach DNA concepts are available. Many of the kits that can be bought are designed for translation only or replication only and can be time consuming to construct. These models all use different parts to represent the molecules involved. This may confuse students if one day the sugar is a blue pop bead and the next day it is a red square pieces of plastic. Computer simulations are also available for use. These allow students to manipulate the molecules and watch the processes unwind. The

major problem with these programs is the cost to the school. It is usually not feasible for a teacher to purchase a site license and software necessary on his/her limited budget. From my experience, I think some students at the high school level are more kinesthetic and need to actually touch the parts to make the processes more concrete and computer models do not allow for this. A short video clip or computer simulation shown by the teacher at some point during instruction may be helpful for students to see the continuous process versus the slower one shown by a model.

I have designed a model that represents DNA structure, RNA structure, DNA replication, transcription and translation all in one. Lessons were designed to be used with the model in an inquiry method of learning. The model was available to the students throughout the unit. The research questions addressed were:

1) Does direct experience with a manipulative assist with student understanding of DNA structure and the process of translation?
2) Does using the same model throughout the learning of DNA and related processes assist in student understanding more than using multiple models each once?

## II. BACKGROUND/LITERATURE REVIEW

### Conceptual Change

Since Piaget's work in the 1920's much has been done to understand the ways in which learners view the natural world and what teachers need to do to aid in conceptual change for learners (Wandersee, Mintzes & Novak, 1994). There is a wide body of research in the area of conceptual change. Much of which has been conducted to determine what conceptions students hold. This has led to investigating the ways to assist student learning of scientific concepts. Concepts that are erroneous in one context can be useful in others (Smith, diSessa, & Roschelle, 1993). This makes it much harder to assist in the movement from nonscientific thinking to scientific thinking. Quite often the concepts held before instruction are still present and often actively defended (Smith, diSessa, & Roschelle, 1993). Since learners have held onto their conceptions for a while before instruction, they are often resistant to change.

Preconceptions have been defined as a concept or idea that a student has when entering a course and will affect the learning in some way (Fisher & Lipson, 1982). These preconceptions can be helpful or harmful to student learning. All students come into the classroom with some background; they are not just blank slates or sponges that absorb information. Chi, Slotta & de Leeuw (1994) described three ontological categories that concepts are placed in: Matter (things), Processes, and Mental States. After concepts are placed into one of these main categories they are then placed in one of many branches. This is important to know when teaching since concepts that are

wrongly placed into a category are much harder to change. The difficulty comes from the incompatibility between the representations the student brings and the instructional context the concept truly belongs (Chi, Slotta & de Leeuw , 1994). The language used to describe the concept is important in placing it in the correct ontological branch. Teachers need to use the correct descriptors when teaching a lesson. With regard to DNA processes, process terms should be used such as “is carried out” or “has a sequence” and not matter terms.

The students’ prior knowledge and how they use it is important in their learning. It can be used to “provide raw materials for formulating scientific theory, supporting qualitative reasoning and mapping everyday situations to theoretical representations” (Smith, diSessa, & Roschelle, 1993). The teacher needs to be aware of the concepts that a student comes into the classroom with because often the student will misinterpret the knowledge provided and use it to support their preconceptions (Wandersee, Mintzes & Novak, 1994). To teach for understanding, a diagnosis of students’ initial understanding of the content knowledge is necessary (Carey, n.d.). This allows the students to show the teacher what they know and provide a starting point for the teacher. The teacher now has an idea of student preconceptions. They can see where students have nonscientific prior concepts to help shift the students towards the scientific view. It serves to activate the prior knowledge in preparation for learning the course content (Buckley, 2000). The pre-test is a tool that may help students to begin thinking about the concept to be taught. By

making students aware of what they think about a concept they may be better able to recognize the errors in their thinking and make the correct adjustments.

In learning, students usually need to assimilate or accommodate their central concepts (Posner, Strike, Hewson & Gertzog, 1982). The assimilation allows them to make small changes to the concepts they currently hold while accommodation is a more radical change of the conceptual framework. Accommodation involves four steps: (1) dissatisfaction with current concept, (2) new concept appears intelligible, (3) new concept appears plausible and (4) the new concept should suggest the possibility of new areas of inquiry (Posner, Strike, Hewson & Gertzog, 1982). For students to completely accept a new concept in place of an old these four steps need to occur. If one is missing the student will not truly accommodate the scientific conception.

Teachers need to be aware of ways to assist in this accommodation and assimilation for student conceptual learning. Some of these techniques focus on the functions of externalizing and modifying the learners' knowledge while others address the need for self monitoring and controlling the events of learning (Wandersee, Mintzes, & Novak, 1994). Learners will resist making changes unless they are dissatisfied with their current conceptions and find an acceptable replacement (Posner, Strike, Hewson &d Gertzog, 1982). Students need to take ownership for their learning to make the conceptual change. Teachers need to help students see the relevance in their life for students to take the time and effort to learn something new, especially if it is at odds with what a student already thinks. Confrontation begins as an external, social interaction in

the classroom, but for it to succeed the confrontation must be internalized by the student (Smith, diSessa, & Roschelle, 1993). Classroom discussion can be important in learning (Smith, diSessa, & Roschelle, 1993). This should be a discussion though and not a lecture presented by the teacher. The more involved the students are the more likely they are to internalize the new concepts. "Appropriately designed interventions can result in rapid and deep conceptual change in relatively short periods" (Smith, diSessa, & Roschelle, 1993). The issue is then to find these appropriate interventions to assist student conceptual change.

With regard to DNA, a pre-test can show the teacher what concepts the students already know and how students are using them. This can guide the discussions that are to be held throughout the unit. By referring to the students answers before and during discussion the teacher can be sure to address the concepts that are not in line with scientific thinking. The more the student thinking is addressed the more likely students are to accommodate their knowledge structures. Having students use a model of DNA to perform processes involved may help them to rethink concepts they hold.

**Model Use in Learning**

Much of biology is invisible to students in the classroom (Fisher & Lipson, 1982). This causes many problems with student understanding of biological concepts. Students have a hard time picturing these abstract concepts by themselves. Modeling exercises are great for enhancing involvement and comprehension of abstract concepts by using them in any of the three phases of the learning cycle (Miller, 1998). It stands to reason the

more concrete an abstract concept can become for students, the better they will learn it. Models allow students to see processes and molecules that are microscopic or too macroscopic to visualize. Since models often have some of the same general properties as the real, but unavailable concepts, they can help students to visualize the simplest ideas that cannot be observed directly (Wilcoxson, Romanek & Wivagg, 1999). These observations are key to understanding for some students. There are learners who do not learn by reading or hearing. They need to touch and observe what is being taught to gain a deeper understanding of the concepts. For a deep understanding teaching needs to focus on the students' ability to organize and access knowledge so they are able to use it and not just reproduce it. Models encourage students to obtain this deeper understanding (Malacinski & Zell, 1996). This deeper understanding helps students toward becoming scientifically literate to make informed decisions as a citizen. Teachers need to strive for this understanding and models can help. "Models are integral to thinking and working scientifically because models are science's products, methods and major learning and teaching tools" (Harrison & Treagust, 2000). To show how things work scientists' use models. Therefore students using models to gain understanding makes sense. The model should allow them to conceptualize the science more than watching or reading about it.

Models are not used only in biology. They are important in all science classrooms since they can be used to show aspects that cannot be reproduced due to safety concerns, time constraints, abstraction or complexity of the phenomenon (Harrison & Treagust, 2000). There are models for concepts in all areas of science. These models are key to

working scientifically since they enhance investigations, understanding and communication within the science community (Harrison and Treagust, 2000). Scientists often use models to represent their work to help others understand it. Without models the concepts and information may be too complex and confusing to comprehend. Model use by students then helps to link many processes that are being taught. To describe the process of DNA translation takes many words that students may not fully understand. Using a model, students can move the parts and form their own descriptions of the processes and begin to internalize what the science is behind the process.

Models are important to learners in many ways. One way mentioned before is to understand phenomena that cannot be seen (Buckley, 2000). Many students have prior knowledge of concepts of phenomena that cannot be seen. For example, DNA is thought of as blood even though students have never seen DNA. In teaching, students need to accommodate their prior knowledge. Models can only work if the students' interests and prior knowledge are accommodated (Harrison & Treagust, 2000). Models also need to be easily understood and remembered by students to act as aids to memory, explanatory tools and learning devices (Harrison & Treagust, 2000). When forming or using a model for teaching, these aspects need to be taken into account. If they are not the models may be ineffective and cause more confusion than they clear up for students. When using models and manipulatives in teaching it is important to have clear directions and explanations for students. When these become too verbose the students do not read or follow what is going on. Students need the model to help simplify written or oral

descriptions of processes. There are many types of models that can be used in teaching. Several of these are: (1) scale models, (2) pedagogical analogical models (3) iconic and symbolic models, (4) mathematical models, (5) theoretical models, (6) maps, diagrams and tables, (7) concept-process models, (8) simulations, (9) mental models, and (10) synthetic models (Harrison & Treagust, 2000). Obviously a teacher does not use all of these in teaching a concept but many of them are used. Mental models are internal, cognitive representations that are used by a learner and influence their learning (Buckley, 2000). These mental models are images that a person draws on when faced with a problem, a question to answer or something they are attempting to understand. A teacher is often trying to help students form a more scientific mental model. When learning, students may reject their current model and form a new one or revise their current model so it represents the new concept more accurately (Buckley, 2000). By using a manipulative model students form a mental model of the processes they are doing. They can internalize the concepts by observing and "doing" the processes. By using a model students can see the unseeable processes, which may challenge their prior knowledge. This challenge is necessary for conceptual changes to occur. By making the concept more concrete students may be better able to see where their prior knowledge falls short. The manipulative that will be used in this lesson represents a pedagogical analogical model since it is sharing information with the target and is teacher crafted to make the non-observable more accessible (Harrison & Treagust, 2000). It will be used to explain structure and function of DNA and RNA including the processes of replication,

transcription and translation. The model will allow students to kinesthetically go through the process. It gives the students control over what they are doing for their learning. By physically modeling translation students can see and control the processes that cannot be easily observed or controlled otherwise. It is one thing to look at a picture but another to make that picture yourself so you see how everything matches and connects. By building the process the students should have ownership of it to help them gain the deep understanding. Students need to have this ownership to truly learn.

**Some Research on Learning DNA and RNA**

In relation to other biological topics, students ranked DNA and RNA in the middle with regard to difficulty (Johnstone & Mahmoud, 1980). This means students are able to understand these concepts, without as much confusion as other concepts, which were ranked as more difficult. This is also important since understanding DNA structure and function is essential for understanding other cellular concepts (Wilcoxson, Romanek and Wivagg, 1999). By ranking DNA in the middle students are indicating they need more help than concepts seen as easier to understand and a model may be able to help. Some of the problems with learning DNA come from the terminology, complex detail, and abstract ideas associated with it (Wilcoxson, Romanek & Wivagg, 1999). All of these issues need to be addressed when teaching these concepts. Since RNA is so similar to DNA many of the same problems are seen. The language of DNA is very similar to a foreign language in which there is a large difference between memorizing and using vocabulary along with listening to language and understanding the language (Malacinski

& Zell, 1996). Language may contribute to the difficulty of learning since the process itself is abstract. If the students do not understand what they are hearing or talking about there is no way for them to learn the concepts. By explaining models using the proper vocabulary they begin to internalize this scientific language and increase their learning and critical thinking skills (Malacinski & Zell, 1996). Students will need to be able to explain what they did with the model in their own words. To do this they will need to internalize the concepts into their framework, by assimilating or accommodating the new knowledge with the old. By the teacher encouraging students to question the components of the model, build interpretations and assess and criticize the validity the discussion can lead to effective learning (James, 1998). The more often students are using the vocabulary of science the more they will internalize the concepts that the teacher is trying to get across, especially once then have made the link between the concepts and the names of the concepts. This connection may help with their conceptual understanding. Ideally what a student takes from a course is a new way of looking at the world and a new language for describing and characterizing that view (Fisher, 1985). This is the goal in creating scientific literate students. Often models are necessary to help students' with DNA and RNA being no exception. The models help students to build their own concepts about scientific processes and look at scientific concepts more scientifically. Students seem to have a belief that amino acids are produced by protein synthesis (Fisher, 1985). This is thought to be from the strong word linkage between amino acids and translation (Fisher, 1985). One important piece to point out is that

twelve amino acids are made through a series of chemical reactions and eight must be obtained by the diet. The difference between amino acid synthesis and their role in protein synthesis needs to be stressed. The model can do this by the amino acids not being made during the process of translation but being present in the "cell". The description in the directions will stress the origination of these amino acids. Students will see how amino acids are carried in and bonded to make the proteins.

In interviewing students that have answered multiple-choice questions relating to amino acids and translation, Fisher (1985) found that most of the students knew the individual facts but could not make the connections through organizing the information. "There were at least four factors found to contribute to the erroneous idea about amino acids and protein synthesis (1) strong word association, (2) confusion with familiar and unfamiliar, (3) conflict between dual roles of a molecule and (4) lack of knowledge about sources of molecules" (Fisher, 1985). These factors would need to be addressed in teaching of protein synthesis to assist students in obtaining the deeper understanding necessary for conceptualizing DNA and RNA. The model will assist in this by students forming their own explanations of the process and not just memorizing a lecture. Also by performing the process they can see where molecules are coming from and how they are being used. The follow-up questions with the model will help stress the roles of these molecules, like enzymes, proteins and amino acids, in the body. This will allow students to form their own conceptions on DNA. They will hopefully accommodate the few concepts they may have had before the unit and also build on these for deeper

understanding. Students do not often hold deep concepts about DNA before learning it. The pretest will show what concepts students hold before the unit. The teacher should then address these concepts in discussion as the model shows the scientific concept. The model may help deepen the concepts they learn. The teacher can use the students' answers on the pre-test to help guide discussions during the unit to address concepts students' hold before the unit begins.

Fisher & Lipson (1982) have done previous research on the learning of DNA and RNA finding that often the problem is in errors of management for students. They are able to understand pieces of the processes but not put them together for the big picture. DNA and RNA processes need to be seen as linked concepts that rely on each other to function. It was found that something inhibits a line of thinking that if translation produces proteins, and enzymes are proteins, then translation produces enzymes (Fisher & Lipson, 1982). It is my hope that using a manipulative throughout the learning of DNA and RNA processes these connections that are necessary will be made. Students will have the manipulative to pull out anytime they are confused to help clear up their thinking. They will use the model to go through the steps involved from DNA replication through translation. This will show the links necessary between DNA and proteins. This can then lead to the discussion of proteins role in traits.

## III. METHODOLOGY

### Subjects

The model was used in high school biology courses. The students ranged in grade levels from ninth to twelfth grades but all were in general biology. The mix of male to female was eighteen male to sixteen female for the experimental group and eighteen male to twenty female for the control group. Thirty-eight students participated in the control group while thirty four participated in the experimental group. The ethnicity was a variety that included Hispanic, African American and white. There was a wide variety of achievement of students in the group with students achieving A's through F's. The average for the experimental group was 74% while the control group was 73%. The general biology is usually a course that is required for graduation so all learning levels of students are present. Both teachers taught the same students all year. A colleague and I, both employed at Loy Norrix high school each taught one control group and one experimental group. Both of us used the same textbook, Modern Biology by Holt, Rinehart & Winston 2002, and many of the same lessons throughout the year. I generally teach with short lecture followed by activities, worksheets or labs. The other teacher lectures most of the block followed by a worksheet for homework and maybe a lab a week. During the DNA unit all lessons assigned were the same for both teachers control and experimental groups. Of course there were individual differences in presentation that cannot be controlled from person to person. The information presented was the same since both teachers worked from the same outline for discussion and worked with the

same textbook and assignments. Prior to the DNA unit both of us had taught units on chemical bonding, biochemistry, cell parts and cellular transport. The chemical bonding unit covered topics including parts of an atom, ionic bonding, covalent bonding, hydrogen bonding and the periodic table and its use. Biochemistry unit covers water and its properties, acids and bases, properties of carbon, and the structure and function of the organic compounds. The cell parts unit covers unicellular and multicellular organisms, prokaryotes versus eukaryotes, all of the organelles and their structure and function, and the organization of multicellualr organisms, The cell transport unit includes the function and process of diffusion, osmosis, carrier transport, active transport, ion diffusion and bulk transport along with cell membrane structure and role in cellular movement. Both of us addressed the same objectives in our teaching.

**Lessons**

A pre-test, see appendix A for pre-test and post-test, was given to both experimental and control groups to assess students' prior knowledge and to help them recognize what they already think about DNA and its processes. The pre-test and post-test were the same and tested concepts on DNA, RNA structures and functions including replication, transcription and translation. The test was out of sixty-three points and included multiple choice and short answer questions. The teachers used these results to lead discussions addressing students concepts held before instruction and help students accommodate to a more scientific thinking. Each individual teacher based on the students' results on the pre-test determined the points for discussion that would address

possible preconceptions. For example, I noticed that a common question missed was that DNA is the blue print for protein synthesis so I was sure to stress the flow of information from DNA through to the protein and how if there is a change in the DNA that the protein will change. The objectives addressed were:

1) Describe the structure of DNA and the importance of the types of bonds
2) Compare DNA to RNA
3) Explain why DNA replication is important to all living things.
4) Explain the role of RNA in living things
5) Explain how DNA is used to make proteins
6) Describe how a mutation in DNA affects a living thing.

Lessons were developed to have students use the model to make DNA structurally show replication, transcription, translation, and compare DNA to RNA. Each lesson has an inquiry process. Students are presented with a question and told which pieces of the model they need. Using these pieces the students work to try to make a DNA model with the correct bonding. There are then more questions that further help students with understanding. Students are frequently asked to draw their model and explain it in their own words. For the replication, transcription and translation the lessons give directions to make the initial model to use for the process. Students work through the process with guided questions and drawing and describing the processes as they go. Also a lesson was done to perform a simulated DNA fingerprinting activity. This lesson presented the students with a paternity case where a surrogate mother claims the child is hers and her husbands. Students use DNA sequences on paper to work through a paper electrophoresis to determine who the father of the child is. These lessons were imbedded

into the teachers entire unit of DNA and its processes; see Appendix B for experimental lesson plans. Besides the model lessons that were done in class there were short lectures/discussions of the processes after students had worked with the model, worksheets for homework that reinforced the concepts being taught. Students had the model available to them to use when doing other assignments. The models were kept in a bag that the students kept on their table so they had easy access if they feel it was helpful in doing their work.

The model lessons were designed to replace the piecemeal models that are used to only show one part of the entire process, see Appendix C for control lesson plans. The control group had three days of lecture that were followed by worksheets that were the same as the experimental group. The lecture was also the same as the experimental group. The control group made models of DNA out of beads that were then used to determine what amino acids their DNA strand coded for. They also used these DNA sequences to determine the mRNA and the tRNA. A different assignment had the students' use given DNA sequence to determine the mRNA, tRNA and then amino acid sequence to then determine the trait. This assignment determined six traits that students then used to draw an organism with these traits. For review they used a purchased kit that had directions and pieces to work through replication, transcription and translation. The control group did the same DNA fingerprinting assignment as the experimental group. A post-test identical to the pre-test was given to both experimental and control groups to test for conceptual change and the depth of understanding gained by students.

**Model**

The models were made from my designed puzzle pieces. This was the first time the model had been used by myself or the other teacher. He was given the model and lessons to try out ahead of using them and I was available to answer any questions that came up. I used the model with my students first so I was able to point out possible problems that I had fixed as I used it since I had designed it. The DNA model shows the deoxyribose, phosphate, and four nitrogen bases and how they bond including the two hydrogen bonds between the adenine and thymine and the three hydrogen bonds between the guanine and cytosine. Individual nucleotides were separate puzzle pieces so there were four different DNA pieces. The RNA model shows the ribose, phosphate and four nitrogen bases. There are four different RNA pieces. The RNA nucleotide puzzle pieces fit with the appropriate DNA nucleotides to show transcription. To show translation ribosomes showing the A and P sites for tRNA bonding were used. The tRNA had detachable nitrogen bases for the amino acids and detachable anitcodons that were used along with mRNA made from transcription. There was a piece of string to represent the nuclear membrane. A second larger string represented the cell membrane so there was a space that represents the cytoplasm. See Appendix D for model and lessons that went with the model.

**Data Collection**

The teachers involved in the study had more than one section of the same level of biology. Each teacher taught one control group and one experimental group. Teachers

were asked to supply what units have been previously covered in their class. They used the model with one class (experimental group) and not with another (control group). The class averages on the pre-test and post-test, covering the stated objectives, for both groups were analyzed using ANOVA. The test was constructed by using test questions that have been used for several years by myself. These questions have come from test banks and my own design. The test was out of sixty-three points with fifteen multiple choice and ten short answer. The multiple choice were worth two points each for a total of thirty points. The short answers were worth different numbers of points depending on the question but worth a total of thirty-three points. In appendix A the answer key has points in parenthesis next to each question. The lessons for each individual teacher were the same for both groups of students except those requiring the use of the model. The control group lessons included three assignments that each made use of a different model. The class averages for the control group on the pre-test and post-test were compared with the experimental group using ANOVA to determine if one model was more affective for student learning than using multiple models.

## IV. RESULTS

Table 1 compares pretest scores to posttest scores for the experimental and control groups. The control group had a mean gain score of approximately twenty while the experimental group had a mean gain score of almost twenty-three. There is a slight difference between the control and experimental groups with the experimental group making a larger gain but it is not statistically significant. Table 2 shows the ANOVA significance scores. Three assignment scores on assignments done by both groups are shown in Table 1 and Table 2. There was no significant difference in the scores of the experimental and control groups for these assignments except for assignment 2. Overall the experimental and control groups seemed to perform in a similar manner on the assignments and post-test after instruction.

Table 1 – Comparison of Pre-test and Post-test Scores and Three Assignments

**Report**

| Group | | Pretest | Posttest | Assign-1 | Assign-2 | Assign-3 | GainScore |
|---|---|---|---|---|---|---|---|
| C | Mean | 15.6316 | 35.2895 | 14.0147 | 15.4412 | 15.8519 | 19.6579 |
| | N | 38 | 38 | 34 | 34 | 27 | 38 |
| | Std. Deviation | 8.40341 | 14.17632 | 6.39186 | 5.85787 | 4.75317 | 13.02238 |
| E | Mean | 13.8235 | 36.7941 | 13.4828 | 12.8500 | 14.1154 | 22.9706 |
| | N | 34 | 34 | 29 | 30 | 26 | 34 |
| | Std. Deviation | 6.67637 | 13.94313 | 4.06747 | 3.32998 | 5.63792 | 12.93922 |
| Total | Mean | 14.7778 | 36.0000 | 13.7698 | 14.2266 | 15.0000 | 21.2222 |
| | N | 72 | 72 | 63 | 64 | 53 | 72 |
| | Std. Deviation | 7.63834 | 13.98792 | 5.41192 | 4.97767 | 5.22936 | 12.99862 |

Table 2 – ANOVA Significance Scores

**ANOVA Table**

| | | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Pretest * Group | Between Groups | (Combined) | 58.661 | 1 | 58.661 | 1.006 | .319 |
| | Within Groups | | 4083.783 | 70 | 58.340 | | |
| | Total | | 4142.444 | 71 | | | |
| Posttest * Group | Between Groups | (Combined) | 40.625 | 1 | 40.625 | .205 | .652 |
| | Within Groups | | 13851.37 | 70 | 197.877 | | |
| | Total | | 13892.00 | 71 | | | |
| Assign-1 * Group | Between Groups | (Combined) | 4.429 | 1 | 4.429 | .149 | .701 |
| | Within Groups | | 1811.484 | 61 | 29.696 | | |
| | Total | | 1815.913 | 62 | | | |
| Assign-2 * Group | Between Groups | (Combined) | 107.007 | 1 | 107.007 | 4.563 | .037 |
| | Within Groups | | 1453.957 | 62 | 23.451 | | |
| | Total | | 1560.965 | 63 | | | |
| Assign-3 * Group | Between Groups | (Combined) | 39.939 | 1 | 39.939 | 1.474 | .230 |
| | Within Groups | | 1382.061 | 51 | 27.099 | | |
| | Total | | 1422.000 | 52 | | | |
| GainScore * Group | Between Groups | (Combined) | 196.921 | 1 | 196.921 | 1.168 | .283 |
| | Within Groups | | 11799.52 | 70 | 168.565 | | |
| | Total | | 11996.44 | 71 | | | |

The mean score for the pre-test for the control group was 15.6 while the experimental group was 13.8 out of sixty-three points possible. The students did not seem to have a lot of preconceptions about DNA. Very few even attempted to answer the short answer questions. Those that did attempt to answer the questions only answered a few of the questions. Many students said they didn't know anything when they were given the pre-test. They were told to try to answer but there is no way to know if they just guessed or had a preconceived idea about the concept.

The students seemed to perform at a slightly lower level than previously. For one teacher the average for the control group for the DNA unit was 64.4% while the average for the semester was 80.5%. The experimental group for the same teacher was 49.4% for the DNA unit while it was 71.7 overall. For the other teacher the average for the control

group for the DNA unit was 63.2% while it was 68.3% overall. The experimental group for the second teacher had an average of 70.9% for the DNA unit while overall this group had an average of 76.9%. This would seem to indicate that the students struggled more with DNA concepts than they did with much of the others they had learned through the semester. Despite these numbers observations made by myself showed that students in the experimental group who had previously not participated much in discussion were more vocal and comfortable to participate. When students were working on the review activity in the experimental group some were able to explain and draw the processes without the model while others only needed it minimally.

The experimental group used the model only when it was needed for assignments with the model. No students asked to use the model or picked one up when they weren't required. This may have been because the model use took up most of the class time so there was not much time to work on assignments without the model in class.

The two teachers used all the same assignments for the control and experimental groups. The outline for the lecture was also the same. Since the teaching style and some assignments were new to the other teacher he stated he was not as comfortable with teaching them. This would lead to some differences in teaching the information and the way it was presented. These are things that are hard to control from person to person. Each day the other teacher was getting ready for teaching I was checking to see if he had questions and made sure things were as close as possible. He used examples of my students work to know what his students should do.

The scores for the two teachers were combined because the model is designed for any teacher to use and not just myself. The model needs to be helpful to students when any teacher uses it. By combining the results it shows how the model works with different teachers instead of individuals.

The scores for assignment 2 were significantly different. This assignment deals with RNA structure and transcription. The model had two assignments that dealt with this section. One that compared DNA to RNA and another that works through transcription. The control group only had a lecture followed by the assignment. Actually seeing the two different nucleotides and working through the process must have helped with understanding.

## V. DISCUSSION

The first research question that was asked was whether direct experience with a manipulative would assist student understanding of DNA structure and the processes of translation. Since the gain scores were not significantly different it does not appear that there was much assistance by the manipulative. By the significant difference that appeared with assignment 2 it does seem that the manipulative did assist in understanding of RNA and transcription. This seems to indicate that the manipulative was able to make the abstract concepts more concrete for this part of DNA learning. High school students are often thought to still be working at the concrete level, which makes abstract concepts harder for them to learn (Malacinski & Zell, 1996). Although the difference was not significant there was a slightly higher gain score by the experimental group. This may mean the experience is slightly helpful. I would like to try it again with some improvements. I still feel that students need to experience what they are learning rather than just hear it. To fully understand a concept students need to internalize what is being taught and assimilate it into their thinking. The manipulative does help them to picture what is happening. The students show this in the experimental group being able to draw the processes without much assistance during the review time.

The manipulative was designed to help eliminate some of the abstractness of DNA and its processes. As Miller (1998) indicates models can be used in any stage of the learning cycle to assist student learning. The model that I designed does seem to help students slightly. It is something that I would use in my classroom again because in

talking to students that used the model they felt it helped to make sense of everything. There was some confusion at the beginning of the unit but by the end most of the students were comfortable using the model and able to converse with myself when I would sit with their groups. Research has shown that students who are actively involved in the classroom will usually understand the concepts better. The model helped to make students more involved, which may have contributed to the slight difference in gain score and the significant difference in assignment 2. Since assignment 2 dealt with RNA and transcription and there were two model activities that students did before this assignment the extra involvement may have contributed to the improved understanding.

The second research question that was addressed was whether using the same model throughout was more helpful to students than using several different models throughout the unit. Again since there was not a significant difference but there was a slight difference it would seem that using the same model throughout might improve understanding. Models have been shown to help students visualize ideas that cannot be seen directly (Wilcoxson, Romanek, & Wivagg, 1999). By using the same model rather than several different students may have been better able to make a mental image they could remember and use during assignment 2 and the post-test. The control group did not have any model to refer to when doing assignment 2 besides the bead model of DNA that they had made. This model could not physically show transcription since it did not come apart to attach RNA nucleotides to it. Students in the control group would have to create

their mental image from pictures in the text or lecture rather than seeing the process occur using a model. Harrison & Treagust (2000) suggest that models need to be easily remembered to assist student learning. Using the same model throughout made it easier for student to remember what they had done with the model. Many of the students' drawings on the post-test for the experimental group were similar to drawings they had made of the model during the learning of the processes.

The students did not seem to have many preconceptions before the unit on DNA. The answers on the pre-test were all over the place. There did not seem to be much of a pattern. In discussion with students many did mention that DNA was found in blood. During class discussions it was stressed that DNA is found in almost all cells. By learning about the function of DNA and discussions on its role in making proteins students began to understand that DNA is found in most cells. Students had already learned about proteins and their role in the body. By understanding proteins role and the link between DNA and proteins students began to understand that DNA is necessary for cells to function. As Smith, diSessa, & Roschelle (1993) point out students learn by interpreting the situation they are presented with by using their existing knowledge. Having existing knowledge of proteins helped students to see the connection between DNA and proteins and their importance to cells. This prior knowledge of proteins was referred to in discussions held with students to help them see the importance of DNA. Students were repeatedly asked to draw the model as they used it and to describe the process in their own words. Several researchers have pointed out that the language of

science is like a foreign language. Many times students just memorize the terms without understanding. Having the students write the answers in their own words and draw the processes helped them to understand what was happening and use the scientific terms in the correct manner. This helped the students to internalize the concepts. As students were working on the model I would stop to talk to them about what was happening. Students were able to question the model and assess what was occurring with the processes. By working through all the processes with the model the students were slightly better able to see the links between all the functions that occur. Students can see the big picture by using the same model over and over. During the review activity the students in the experimental group seemed to not have as many questions about what process followed the first one and what needed to be done with the model they were working with. This may have been that the experimental group was more comfortable with the model than the control group but I also think that the experimental group had a better understanding of the overall picture of the processes of DNA.

**Sources of Error/Improvements**

Although there was no significant difference in gain scores between the experimental and control groups the experimental group had a slightly larger gain score. They started at a lower mean on the pre-test and finished with a higher mean on the post-test. Therefore there may be some small advantage to using the manipulative over a more traditional lecture style of learning. I feel that it would be worthwhile to attempt a

comparison again but with some changes. There were some issues involved in the study that may be changed to show better results.

One of the major issues with the study was the newness of the manipulative to both teachers and the learning style to the students. This was the first time that both teachers had used this manipulative and with more experience in using it they would be more comfortable and better able to assist student learning. In talking to the other teacher he said he would feel more comfortable the more he used the model. I also feel this way. Both agreed they would use the manipulative again. One of the teachers has a teaching style of transmission with very few hands on activities, while the other uses more hands on activities but not many are as student/inquiry driven as this. For the students to attempt inquiry learning with little or no prior experience is difficult. If a group of students who are used to inquiry learning were involved they may show better results.

The lower scores on the DNA unit may have been from several reasons. One mentioned earlier may have been that students struggled more with this topic. This is documented by Johnstone & Mahmoud (1980) who surveyed students that ranked DNA in the middle in regards to hardness. Another reason for the difference may be that the unit was taught at the end of the first semester so students were not as excited about learning and knew that their semester grades were not going to change a whole lot from the one unit. Students seem to be a lot less organized by the end of the semester and lose papers or forget to turn things in at that time. Due to this students may have done the

work but not turned in the assignments which would affect their averages for the unit of DNA.

The manipulative did seem to help student become more comfortable with the concepts they were learning. In observations made by myself I noticed students who were normally quiet during discussion contributing more and also more excited about learning. However there were also those who seemed to be confused by this learning method. It shows that all learning styles need to be addressed and not just one method. When reviewing before the test it seemed that students in the experimental group were more comfortable with the material than those in the control group. Possibly with a larger group of students the results would be more significant.

In talking to students the majority said that it helped them in learning more than just the lecture. It seemed like the students were able to remember what they had learned later in the year better. When discussing topics that related to DNA and its processes I could refer back to the model and students would respond “Oh yeah”. Overall most students said that they liked the model and it helped them to learn the concepts. I will definitely use the manipulative again and even use others in other lessons. I feel that even though the gain was not significant with more time and experience by the teacher it will be more beneficial to the students.

**Implications**

The slightly greater improvement in gain score by the experimental group would seem to imply that using the same model to learn a concept is beneficial. This type of

learning style may be helpful to learning other concepts also. I intend to use more manipulative type models in my teaching based on the students' comments during this unit. It would seem that students might be better able to see the big picture by using a manipulative. Some students however did complain that they were more confused by using the model exclusively. This would imply that some students require more than just an inquiry type of learning. All learning types need to be addressed in a classroom for all students to succeed.

By there only being a slight increase in the gain scores it would also imply that there should be some changes to the way the model is used in the classroom. I still feel that the model is beneficial to the classroom and that students gain more from the use of the model than not using it. The results not being significantly different implies that more research needs to be done. Modifications need to be made to the model and it needs to be tried with other classes and teachers who have used an inquiry method. The only way the science education can be improved is to continue to try new methods and improve upon those that show a slight gain so that they can have an even greater gain.

Appendix A

DNA Pre-test and Post-test Student Sheet and Answer Key

DNA Pre-Test/Post Test

Answer the following questions to the best of your ability. This will be scored as either credit or no credit so there is no penalty for a wrong answer. The teacher will use this to help see what you already know about DNA and it processes.

1. ____ When does DNA replication occur?
   A. after cell division B. before cell division C. during cell division

2. ____ Which of the following carries out protein synthesis?
   A. CNA B. DNA C. MNA D. RNA

3. ____ What is the reason for transcription?
   A. to form proteins from mRNA code C. to copy DNA code to mRNA
   B. to carry the amino acids to mRNAD. to make a new DNA strand

4. ____Which of the following is the blue print for protein synthesis?
   A. DNA B. mRNA C. tRNA D. rRNA

5. ____ Complementary base pairing links
   A. amino acids B. nitrogen carrying bases C. phosphate groups D. proteins

6. ____ In a DNA molecule adenine always bonds with ___ and guanine always bonds with __.

A. cytosine, thymine B. guanine, cytosine C. thymine, adenine D. thymine, cytosine

7. ____ Which of the following type of RNA carries the amino acids?
   A. mRNA B. rRNA C. tRNA D. xRNA

8. ____ What is the structure of DNA?
   A. single strand helix C. double strand helix
   B. single strand straight D. double strand straight

9. ____ The sequence of bases in DNA is GCAT what would be the complimentary strand?
   A. GCAT B. CGUA C. CGAT D. CGTA

10. ____ A nucleotide consists of
   A. a sugar, a protein, and adenine.
   B. a sugar, an amino acid, and starch.
   C. a sugar, a phosphate group, and a nitrogen-containing base.
   D. a starch, a phosphate group, and a nitrogen-containing base.

11. ____ RNA is chemically similar to DNA except that its sugars have an additional oxygen atom, and the base thymine is replaced by a structurally similar base called
A. uracil. B. cytosine. C. alanine. D. codon.

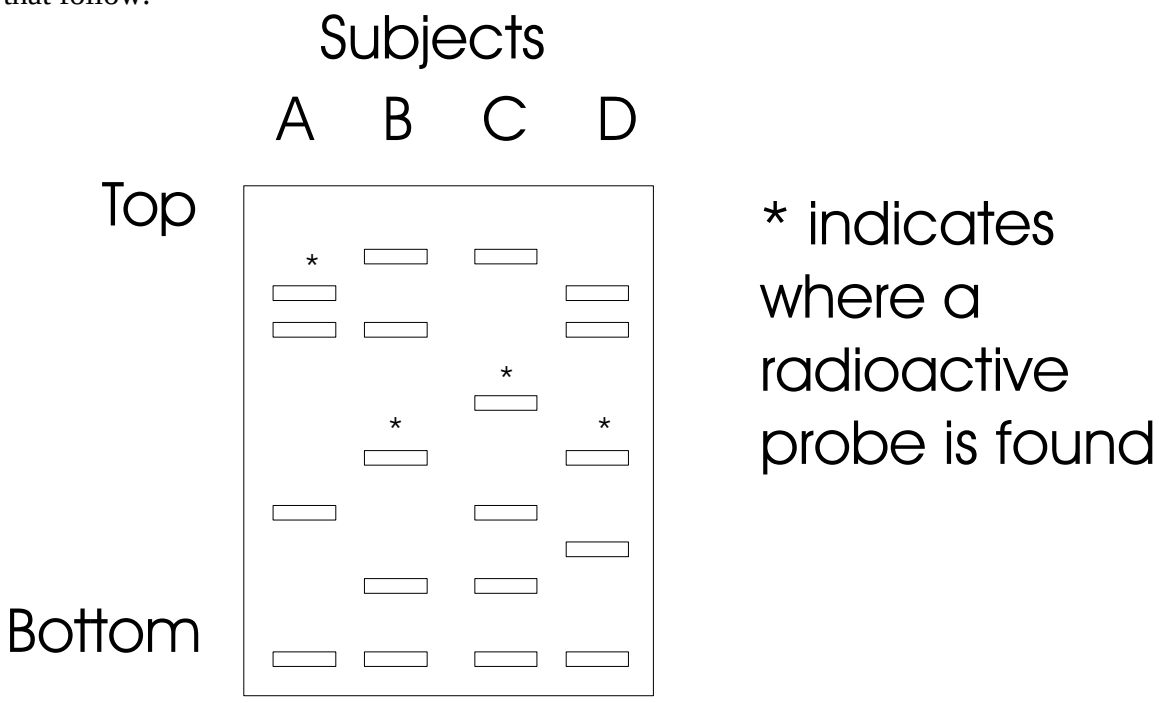
12. ____ The function of rRNA is to
A. synthesize DNA. B. form ribosomes.
C. synthesize mRNA. D. transfer amino acids to ribosomes.

13. ____ Refer to the codon chart. What is the portion of the protein molecule coded for by the piece of mRNA shown in the diagram?
**mRNA:** CUCAAGUGCUUC
A. Ser—Tyr—Arg—Gly B. Leu—Lys—Cys—Phe
C. Val—Asp—Pro—His D. Pro—Glu—Leu—Val

14. ____ If the following is a sequence of DNA what would be the mRNA formed?
AGCTTA
A. AGCUUA B. TCGAAT C. UCGAAU D. AGCTTA

15. ____ During translation in eukaryotes, anticodons
A. never bind to the mRNA codons.
B. assist in the assembly of fats.
C. consist of a five-nucleotide sequence at one end of the transfer RNA molecule.
D. ensure that each amino acid is delivered to its proper “address” on the mRNA.

Short answer – Attempt to answer each question.
Look at the following diagram of an electrophoresis gel and answer the questions 16-18 that follow.




16. Which fragments are the smallest?
17. Which two people are related?
18. Why are they related?

19. What are three differences between DNA and RNA?

20. Why is DNA replication necessary for life?

21. Draw a picture of DNA and label the nitrogen bases, the sugar and phosphate. Include where the covalent bonds and the hydrogen bonds are located.

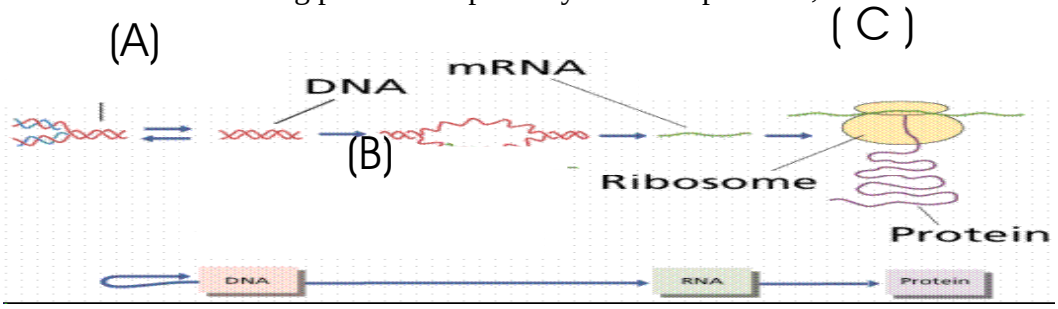
22. Describe the process of DNA replication including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

23. If a cell were no longer able to produce RNA of any kind how would that cell be affected? What would it still be able to do and what wouldn't it be able to do?

24. Describe the process of DNA transcription including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

25. Describe the process of translation of mRNA including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

26. Fill in the missing parts to the pathway below at points A, B and C.




27. A mutation occurs in a lung cell DNA due to overexposure to cigarette smoking. This mutation is a deletion of a nucleotide early in the sequence for a protein. Describe what this mutation means to the cells processes and how these would change.

Answer Key

DNA Pre-Test/Post- Test

Answer the following questions to the best of your ability. This will be scored as either credit or no credit so there is no penalty for a wrong answer. The teacher will use this to help see what you already know about DNA and it processes.

1. __B__ When does DNA replication occur?
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2. __D__ Which of the following carries out protein synthesis?
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3. _C___ What is the reason for transcription?
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5. __B__ Complementary base pairing links
   A. amino acids B. nitrogen carrying bases
   C. phosphate groups D. proteins

6. _D__ In a DNA molecule adenine always bonds with ___ and guanine always bonds with __.
A. cytosine, thymine B. guanine, cytosine C. thymine, adenine D. thymine, cytosine

7. __C__ Which of the following type of RNA carries the amino acids?
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8. __C__ What is the structure of DNA?
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9. _D___ The sequence of bases in DNA is GCAT what would be the complimentary strand?
   A. GCAT B. CGUA C. CGAT D. CGTA

10. _C___ A nucleotide consists of

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B. a sugar, an amino acid, and starch.
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A. synthesize DNA. B. form ribosomes.
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13. _B___ Refer to the codon chart. What is the portion of the protein molecule coded for by the piece of mRNA shown in the diagram?

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A. Ser—Tyr—Arg—Gly B. Leu—Lys—Cys—Phe
C. Val—Asp—Pro—His D. Pro—Glu—Leu—Val

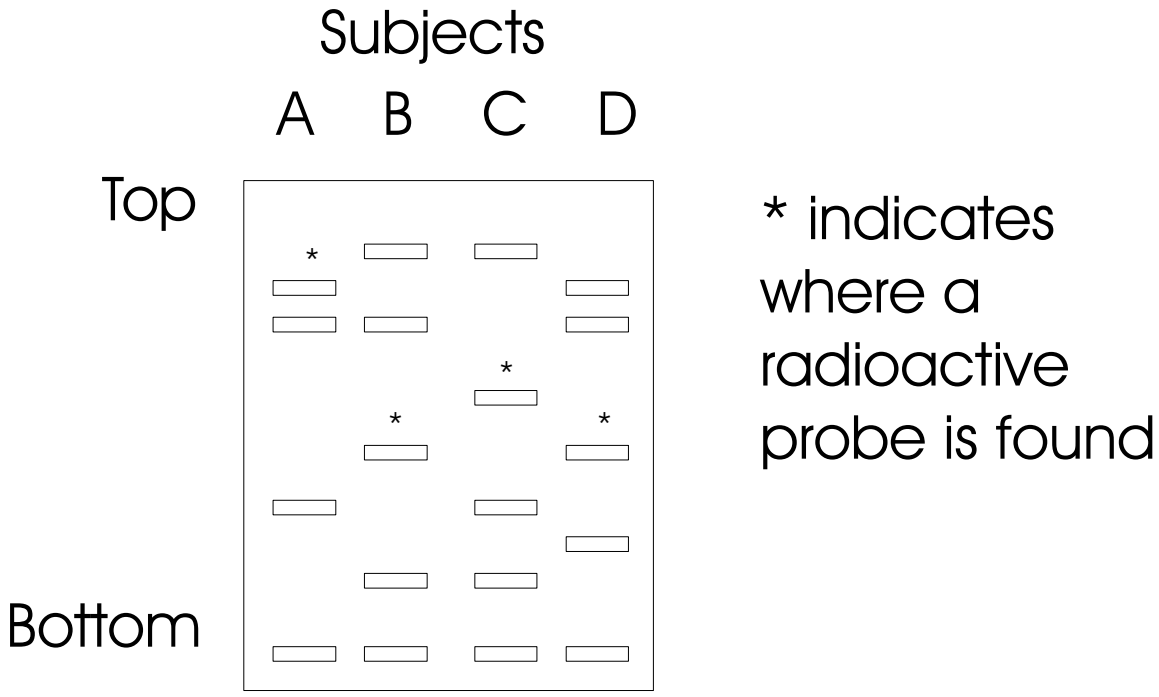
14. __C__ If the following is a sequence of DNA what would be the mRNA formed? AGCTTA

A. AGCUUA B. TCGAAT C. UCGAAU D. AGCTTA

15. __D__ During translation in eukaryotes, anticodons

A. never bind to the mRNA codons.
B. assist in the assembly of fats.
C. consist of a five-nucleotide sequence at one end of the transfer RNA molecule.
D. ensure that each amino acid is delivered to its proper “address” on the mRNA.

Short answer – Attempt to answer each question. The number of points each question is worth is in parenthesis next to the number.
Look at the following diagram of an electrophoresis gel and answer the questions 16-18 that follow.




(1)16. Which fragments are the smallest? top
(1)17. Which two people are related? B & D
(1)18. Why are they related? They have the probe at the same location

(3)19. What are three differences between DNA and RNA? Order may vary
1) RNA is single stranded and DNA is double stranded
2) RNA has uracil while DNA has thymine
3) RNA has the sugar ribose while DNA has deoxyribose
4) RNA leaves the nucleus while DNA does not

(2)20. Why is DNA replication necessary for life?
DNA replication is necessary to allow all cells to have the same DNA sequences in them. Before cells divide they make a copy of the DNA so the new cells both have the same DNA. If this did not occur then the new cells would be missing information from the DNA

(4) 21. Draw a picture of DNA and label the nitrogen bases, the sugar and phosphate. Include where the covalent bonds and the hydrogen bonds are located. Sequence of nucleotides may vary as long as the correct complimentary pairs are shown

_____

ATCGGACGTACGATT- nitrogen base, hydrogen bonds (Picture one point and each label

**TAGCCTGCATGCTAA** **one point.)**

Sugar and phosphate⇑, covalent bonds

(4)22. Describe the process of DNA replication including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

1) DNA replication occurs in the nucleus (1)
2) DNA separates down the middle between the nitrogen bases at the hydrogen bonds
3) Complimentary nucleotides that are floating in nucleus attach to the correct nucleotides
4) The DNA continues to unwind and nucleotides continue to attach until there are two identical copies of the DNA

(3) 23. If a cell were no longer able to produce RNA of any kind how would that cell be affected? What would it still be able to do and what wouldn't it be able to do?

If the cell could no longer produce RNA than none of the DNA information would be able to leave the nucleus and no proteins would be made.(1) The cell would still be able to copy DNA.(1) The cell would not be able to perform transcription or translation.(1)

(4) 24. Describe the process of DNA transcription including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

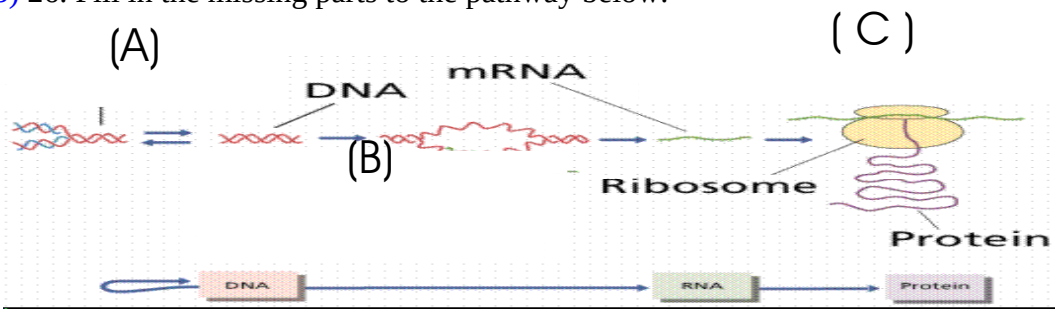
1) Transcription takes place in the nucleus. (1)
2) DNA separates down the middle between the nitrogen bases at the hydrogen bonds.
3) Complimentary RNA nucleotides in the nucleus attach to the correct DNA nucleotides.
4) The RNA detaches from the DNA as it is made and the DNA goes back together.
5) The RNA leaves the nucleus.

(4) 25. Describe the process of translation of mRNA including where it occurs and the steps involved. You may draw a picture if you like but include descriptions also.

1) Translation occurs in the cytoplasm on the ribosome. (1)
2) The ribosome attaches to the mRNA at AUG and the tRNA with the anticodon bonds to the mRNA.
3) The ribosome slides over so the next codon is available and the tRNA with the anticodon bonds to the mRNA.
4) The amino acids on the two tRNAs in the ribosome bond using a peptide bond.

5) The first tRNA leaves the ribosome and the ribosome moves over for the next codon to bond with its tRNA.
6) Process continues until a stop codon is reached which is when the polypeptide chain is complete.

(3) 26. Fill in the missing parts to the pathway below.




a) replication
b) transcription
c) translation

(3) 27. A mutation occurs in a lung cell DNA due to overexposure to cigarette smoking. This mutation is a deletion of a nucleotide early in the sequence for a protein. Describe what this mutation means to the cells processes and how these would change.
A mutation in the DNA would then change the nucleotide sequence and therefore the RNA that is made from the DNA. This would then change the amino acids that are made from the DNA. The wrong protein would be made so it could not do its job.

# Appendix B

## Experimental Lesson Plan of Specific Lessons to Use with DNA/RNA Models

Experimental Lesson Plan of Specific Lessons to Use with DNA/RNA Models

**Day 1 – Lessons 1 & 2**

**Lesson 1 -** Time - ~ 30 minutes - Pretest

When to use:

1) Use this lesson before starting any instruction for the DNA unit. This unit should be taught after units have been taught covering cell structure, cell transport, chemical bonding and organic compounds including the monomers.

Objectives:

1) Students will show what concepts they currently hold about DNA and the processes involved with DNA.

Lesson: - Uses Pretest

1) Students will take a pre-test over the concepts to be taught. Have students take pretest. Tell students there is no penalty for wrong answers and credit will be given just for taking the test. Allow approximately thirty minutes to take the test.

**Lesson 2 –** Time - ~ 60 minutes - DNA Structure

When to use:

1) Use this lesson before discussion on DNA structure including the nucleotides structure.

Objectives:

1) Students will gain an understanding of the parts of a nucleotide.
2) Students will recognize how the nucleotides bond to make DNA structure.
3) Students will gain understanding of the bonds involved in a DNA molecule.

Lesson: - Uses DNA Structure hand out with guided questions found in appendix D.

1) Students will use guided questions to observe nucleotide structure and differences between the four kinds of nucleotides for DNA. Have students work with a partner to go through the questions on the handout dealing with the nucleotides.
2) Students will use guided questions to build a DNA model and describe how and why they built it in the manner they did. Have students work with a partner to go through the questions on the hand out dealing with DNA structure.
3) Students will use guided questions to describe the type of bonding used in building a DNA molecule. Have students work with a partner to answer questions on the hand out dealing with bonding in DNA structure.

Follow-up:

1) Class discussion building on model of the structure of DNA and nucleotides including the importance of the types of bonding led by teacher. Discussion

2) should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.

**Day 2 – Lesson 2**

**Lesson 3** – Time - ~ 90 minutes – DNA Replication

When to use:

1) Use this lesson when introducing DNA replication.

Objectives:

1) Students will be able to describe how DNA replication occurs.
2) Students will be able to explain the importance of DNA replication in living things.

Lesson: - Uses DNA Replication handout with guided questions found in appendix D.

1) Students will build a DNA model of a given length of nucleotide pairs. Have students work in pairs to build a DNA model following the instructions on the DNA replication handout.
2) Students will use this model and guided questions to perform DNA replication. Have students work in pairs to go through questions dealing with DNA replication.
3) Students will use guided questions to recognize when DNA replication occurs and the importance.

Follow-up:

1) Class discussion building on model of DNA replication including the importance of the types of bonds in DNA to allow replication to occur. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.
2) Class discussion building on model of when replication must occur and why it is important. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.
3) Assignments that will reinforce these concepts. Worksheet 10-1 DNA designed by textbook Modern Biology, Holt, Rinehart & Winston, 2002.

**Day 3 – Lessons 4 & 5**

**Lesson 4 –** Time – ~ 30 minutes – RNA Structure

When to use:

1) Use this lesson when introducing RNA.

Objectives:

1) Students will be able to compare the nucleotides of DNA to RNA.

Lesson: Uses RNA Structure handout with guided questions found in appendix D.

1) Students will use guided questions to observe the RNA nucleotides and compare and contrast them to DNA nucleotides. Have students work in pairs to go through the questions dealing with RNA nucleotides.
2) Students will begin to gain understanding of the role of RNA.

Follow-up:

1) Class discussion building on model of RNA nucleotides and the similarities and differences to DNA. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E
2) Class discussion building on model of how DNA structure compares and contrasts to RNA structure. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.

**Lesson 5 –** Time - ~ 60 minutes - Transcription

When to use:

1) Use this lesson when introducing the process of transcription.

Objectives:

1) Students will be able to describe the process of transcription.
2) Students will be able to compare and contrast DNA structure to RNA structure.
3) Students will begin to gain understanding of the role of RNA.

Lesson: Uses Transcription hand out with guided questions found in appendix D.

1) Students will build a model of DNA with a given number of nucleotide pairs. Have students build a model using the instructions in the transcription hand out.
2) Students will use this model of DNA with guided questions to perform the process of transcription. Have students work with a partner to go through the questions on the transcription handout.
3) Students will use guided questions to begin to see the role of RNA for DNA to be able to function.

Follow-up:

1) Class discussion building on model of the process of transcription and how this compares and contrasts to replication. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.
2) Class discussion building on model of how DNA structure compares and contrasts to RNA structure. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.
3) Class discussion building on model of what RNA can do that DNA cannot and the importance of this. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion found in appendix E.
4) Assignments that reinforce these concepts. Worksheet 10-2 RNA designed by textbook Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 4 – Lesson 6**

**Lesson 6 -** Time - ~ 90 minutes - Translation

When to Use:

1) Use this lesson when introducing the process of translation.

Objectives:

1) Students will gain an understanding of the process of translation.
2) Students will be able to explain how DNA is used for making proteins.
3) Students will recognize how a mutation can affect the translation process.

Lesson: Uses translation handout guided questions found in appendix D.

1) Students will build a model of RNA with a given number of nucleotides. Have students work with a partner to build an RNA molecule following directions in the translation handout
2) Students will use this model with guided questions to perform the process of translation. Have students work in pairs to go through the questions dealing with translation.
3) Students will use the same model of RNA but this time change a nucleotide to represent a mutation. Have students follow directions in translation handout to change a nucleotide in their RNA strand.
4) Students will use this model with guided questions to perform the process of translation. Have students work with a partner to go through the questions dealing with mutations in the translation handout.
5) Students will compare the polypeptide chain made the second time with the first polypeptide chain made. Have students follow the directions in the translation handout to compare the new polypeptide with the old.

Follow-up:

1) Step 2 of the lesson should be followed by a class discussion building on the model of the process of translation including the parts that are necessary and where these parts were originally made. It should be stressed that the amino acids are not being made but were made in a different process or obtained from the diet. The discussion should also include the organism uses for the proteins that are made. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion is in appendix E.
2) Step 5 of the lesson would be followed by a class discussion building on the model of how the mutation changed the polypeptide and what this would mean to the organism. Mutagens should be included in this discussion and also how the cell quite often fixes mutations that occur. Discussion should include concepts from pre-test that need to be addressed. Outline for discussion is in appendix E.
3) Assignments that will reinforce these concepts. Worksheet 10-3 Protein Synthesis designed by textbook Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 5 – Lesson 7**

**Lesson 7 –** Time – 90 minutes – DNA Fingerprinting

When to use:

1) Use this lesson towards the end of the unit on DNA when ready to discuss technological uses of DNA such as DNA fingerprinting.

Objectives:

1) Students will become familiar with how DNA fingerprinting is used to identify relationships between people and also link them to crime scenes.
2) Students will recognize that DNA is not only found in blood.

Lesson: Uses DNA Fingerprinting handout.

1) Students will be given a scenario that involves a surrogate mother who is claiming that the father of the child is not the sperm donor but her own husband and therefore she is claiming she should be allowed to keep the child. – Read situation to students and explain what surrogacy is. Point out that this occurs often and this situation has occurred in real life.
2) Students will read background information on what gel electrophoresis is and the steps involved for performing this process and answer questions based on the reading. Have students read the first page of the handout and answer the questions on the second page. Give students approximately twenty minutes to do this. Briefly talk about the process after students have read it.
3) Students will then be given a specific DNA sequence to use during the lesson. These sequences will be different for the mother, sperm donor, husband and child. Hand out DNA sequences to students who are sitting in groups of five so each person has a different sequence for the activity.
4) Using guided questions the students will perform a gel electrophoresis with their model and determine who the father of the child actually is and who should be allowed to keep the child. Go through the directions with the students and have them perform each direction to create a paper "gel" to determine the father. Where there are matches with the "radioactive probe" (highlighted spots) there is a genetic relationship.

Follow-up:

1) Class discussion on who the father of the child was and the evidence used to support their conclusion. Include in discussion how this process is used in real life. Also discuss where samples can be taken. Discussion should include concepts from pre-test that need to be addressed. Students should find that the sperm donor is the father. Review the process of electrophoresis. Outline for discussion in appendix E.
2) Assignments that will reinforce these concepts - DNA and Transcription/Translation summary handout.

**Day 6 – Lesson 8**

**Lesson 8 (review)** – Time - ~ 90 minutes - Review Activity

When to use:

1) Use this lesson a day or two before the test.

Objectives:

1) Students will be able to revisit the concepts taught over the time of the unit and perform and explain them on their own.

Lesson: Uses the review activity hand out found in appendix E.

1) Students will create a DNA model and use this to perform DNA replication, transcription and translation. Have students work in pairs to go through all steps in hand out. They will review all processes that they have done in previous activities.
2) Students will describe these processes in their own words. Have students describe on the hand out what they observe with the model.
3) Students will use the models to be able to compare and contrast DNA to RNA in both structure and function.

Follow-up:

1) Allow students to ask about anything that they are still confused on and answer these questions. Go over the processes and questions in hand out with students after all have finished to be sure everyone understands

**Day 7 – Textbook review questions and teacher designed review sheet.** Textbook review questions are on pages 198-199 in Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 8 – Lesson 9**

**Lesson 9 –** Time - ~ 45 minutes - Posttest

When to use:

1) Use this lesson at the very end of the unit on DNA

Objectives:

1) Students will show what they have learned about DNA throughout the unit.

Lesson: Uses Posttest found in appendix A.

1) Students will take a post-test over the concepts that have been taught.

Appendix C

Control Lesson Plan of Specific Lessons to Use with DNA/RNA Models

Control Lesson Plan of Specific Lessons to Use with DNA/RNA Models

**Day 1 – Lessons 1 & 2**

**Lesson 1 -** Time - ~ 30 minutes - Pretest

When to use:

1) Use this lesson before starting any instruction for the DNA unit. This unit should be taught after units have been taught covering cell structure, cell transport, chemical bonding and organic compounds including the monomers.

Objectives:

1) Students will show what concepts they currently hold about DNA and the processes involved with DNA.

Lesson: Uses Pretest found in appendix A

1) Students will take a pre-test over the concepts to be taught. Have students take pretest. Tell students that there is no penalty for wrong answers and credit will be given just for trying.

**Lesson 2 –** Time - ~ 60 minutes - Lecture and worksheet

Objectives:

1) Students will gain an understanding of the parts of a nucleotide
2) Students will recognize how the nucleotides bond to make DNA structure.
3) Students will gain understanding of the bonds involved in a DNA molecule.
4) Students will be able to describe how DNA replication occurs.
5) Students will be able to explain the importance of DNA replication in living things.

Lesson:

1) Students will take lecture notes and discuss with teacher DNA structure and DNA replication. Discussion should include points from pre-test that need to be addressed. Outline for lecture in appendix E.

Follow-up:

1) Assignments that will reinforce these concepts – worksheet 10-1 DNA designed by textbook Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 2 –**

**Lesson 2 – Time - ~ 90 minutes –** DNA Bead Models

Objectives:

1) Students will recognize how the nucleotides bond to make DNA structure.
2) Students will gain understanding of the bonds involved in a DNA molecule.

Lesson: Uses DNA model handouts.

1) Students will build a DNA model of a given length of nucleotide pairs using beads and wire. Have students follow directions in hand out to make a key chain model of DNA.
2) Students will use this model to give a transcribed line of RNA and the three amino acids that are coded by it. Have students answer questions on hand out that goes with DNA model.
3) Students will answer questions based on their model. Have students answer questions on the model handout.

Follow-up:

1) Class discussion building on model. Discussion should include points from pre-test that need to be addressed. Go over the model questions and how the model is similar to and different from actual DNA.

**Day 3 –**

**Lesson 3 –** Time – ~ 90 minutes – Lecture DNA vs. RNA and transcription

Objectives:

1) Students will be able to compare the nucleotides of DNA to RNA.
2) Students will be able to describe the process of transcription.
3) Students will be able to compare and contrast DNA structure to RNA structure.
4) Students will begin to gain understanding of the role of RNA.

Lesson:

1) Students will take lecture notes and discuss with teacher how DNA and RNA compare and the process of transcription. Discussion should include points from pre-test that need to be addressed. Outline for discussion is in appendix E.
2) Class assignment working through examples of transcription and the amino acids coded by RNA. Go over handout Dry Lab 1with students.

Follow-up:

1) Assignments that will reinforce these concepts. Worksheet 10-2 RNA designed by textbook, Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 4 –**

**Lesson 4 -** Time - ~ 90 minutes – Translation lecture and Protein synthesis worksheet.

Objectives:

1) Students will gain an understanding of the process of translation.
2) Students will be able to explain how DNA is used for making proteins.
3) Students will recognize how a mutation can affect the translation process.

Lesson:

1) Students will write lecture notes on translation, mutagens and mutations and discuss the process with the teacher. Discussion should include points from pre-test that need to be addressed. It should be stressed that the amino acids are not being made but were made in a different process or obtained from the diet. The discussion should also include the organism uses for the proteins that are made. Outline for discussion is found in appendix E.
2) Assignment that creates features from DNA code through transcription and translation. Use a protein synthesis worksheet. Go through the first trait with students and then have them finish the last five traits to then draw the organism and answer the questions that follow.
3) Assignments that will reinforce these concepts. Worksheet 10-3 Protein synthesis designed by textbook Modern Biology, Holt, Rinehart and Winston, 2002.

**Day 5 –**

Lesson 5 – **Time – 90 minutes – DNA fingerprinting**

When to use:

1) Use this lesson towards the end of the unit on DNA when ready to discuss technological uses of DNA such as DNA fingerprinting.

Objectives:

1) Students will become familiar with how DNA fingerprinting is used to identify relationships between people and also link them to crime scenes.
2) Students will recognize that DNA is not only found in blood.

Lesson: Uses DNA Fingerprinting handout.

1) Students will be given a scenario that involves a surrogate mother who is claiming that the father of the child is not the sperm donor but her own husband and therefore she is claiming she should be allowed to keep the child. – Read situation to students and explain what surrogacy is. Point out that this occurs often and this situation has occurred in real life.
2) Students will read background information on what gel electrophoresis is and the steps involved for performing this process and answer questions based on the reading. Have students read the first page of the handout and answer the questions on the second page. Give students approximately twenty minutes to do this. Briefly talk about the process after students have read it.
3) Students will then be given a specific DNA sequence to use during the lesson. These sequences will be different for the mother, sperm donor, husband and child. Hand out DNA sequences to students who are sitting in groups of five so each person has a different sequence for the activity.

4) Using guided questions the students will perform a gel electrophoresis with their model and determine who the father of the child actually is and who should be allowed to keep the child. Go through the directions with the students and have them perform each direction to create a paper "gel" to determine the father. Where there are matches with the "radioactive probe" (highlighted spots) there is a genetic relationship.

Follow-up:

1) Class discussion on who the father of the child was and the evidence used to support their conclusion. Include in discussion how this process is used in real life. Also discuss where samples can be taken. Discussion should include points from pre-test that need to be addressed. Students should find that the sperm donor is the father. Review the process of electrophoresis. Outline for discussion in appendix E.
2) Assignments that will reinforce these concepts- DNA and Transcription/Translation summary handout.

**Day 6 –**

**Lesson 6 (review)** – Time - ~ 90 minutes. – Review Activity

When to use:

1) Use this lesson a day or two before the test.

Objectives:

1) Students will be able to revisit the concepts taught over the time of the unit and perform and explain them on their own.

Lesson:

1) Using a kit bought from a science company, students will create a DNA model and use this to perform DNA replication, transcription and translation. Have students work in pairs to go through each step of the directions from the kit to perform all processes of DNA.
2) Students will describe these processes in their own words. Have students write their own descriptions.
3) Students will use the models to be able to compare and contrast DNA to RNA in both structure and function. Have students answer all questions on the model hand out.

Follow-up:

1) Allow students to ask about anything that they are still confused on and answer these questions. Go over answers to questions on the review hand out.

**Day 7 – Textbook review questions and teacher designed review sheet. Review question are found in <u>Modern Biology,</u> Holt, Rinehart and Winston, 2002, pages 198 – 199.**

**Day 8 –**
**Lesson 8 –** Time - ~ 45 minutes - Posttest
When to use:

1) Use this lesson at the very end of the unit on DNA

Objectives:

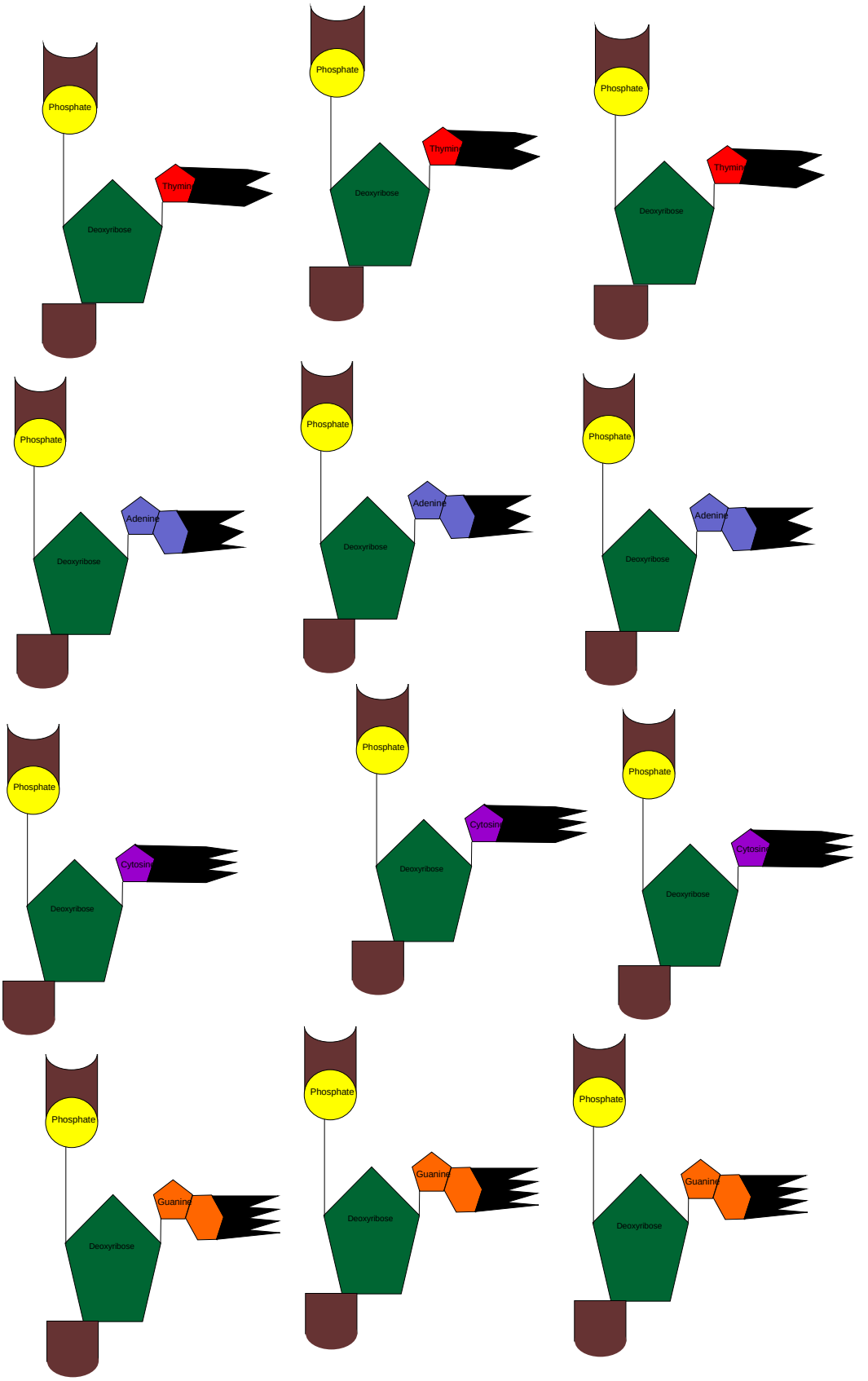
1) Students will show what they have learned about DNA throughout the unit.

Lesson:

1) Students will take a post-test over the concepts that have been taught

# Appendix D

## Model and Student and Teacher Lessons Using the Model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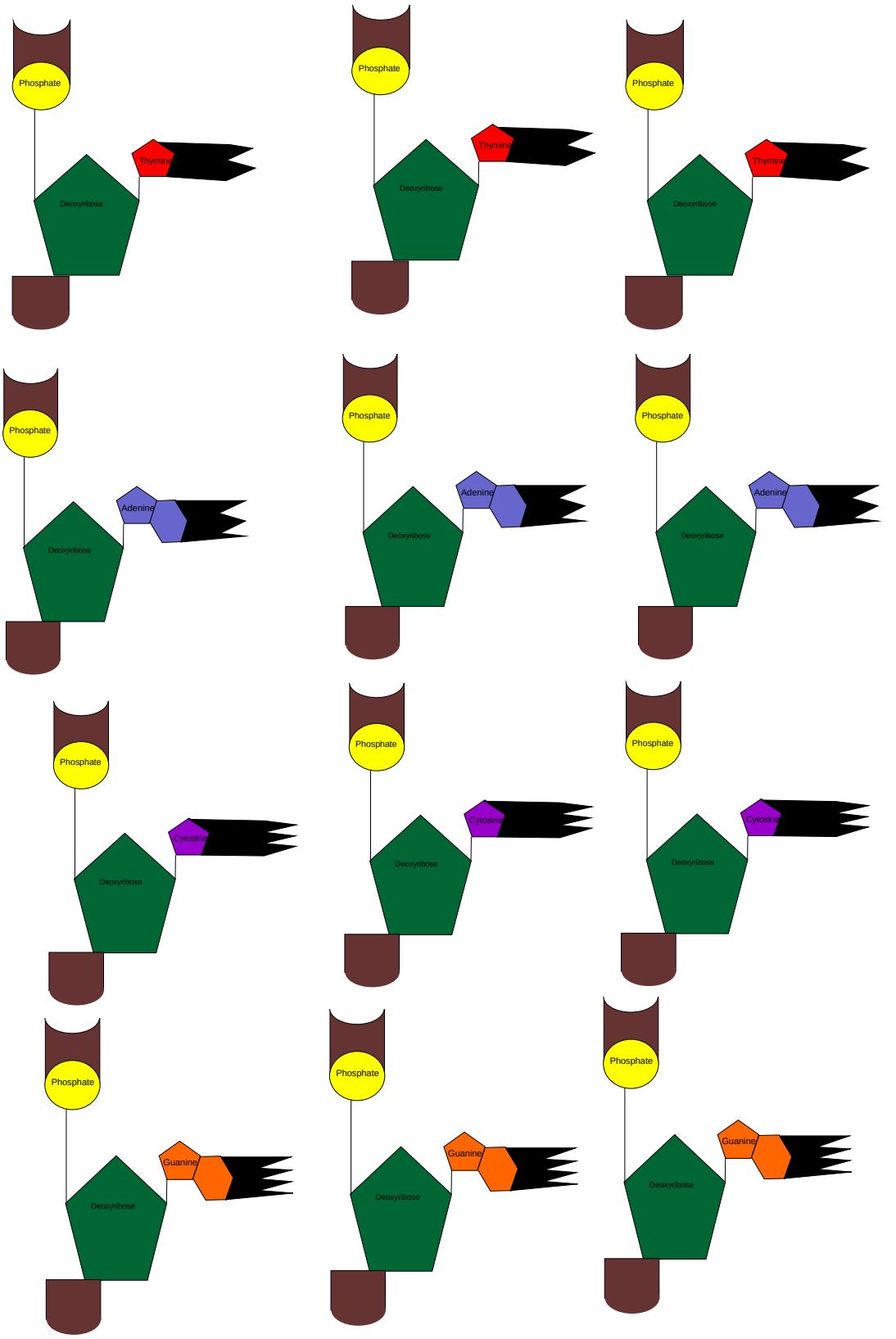
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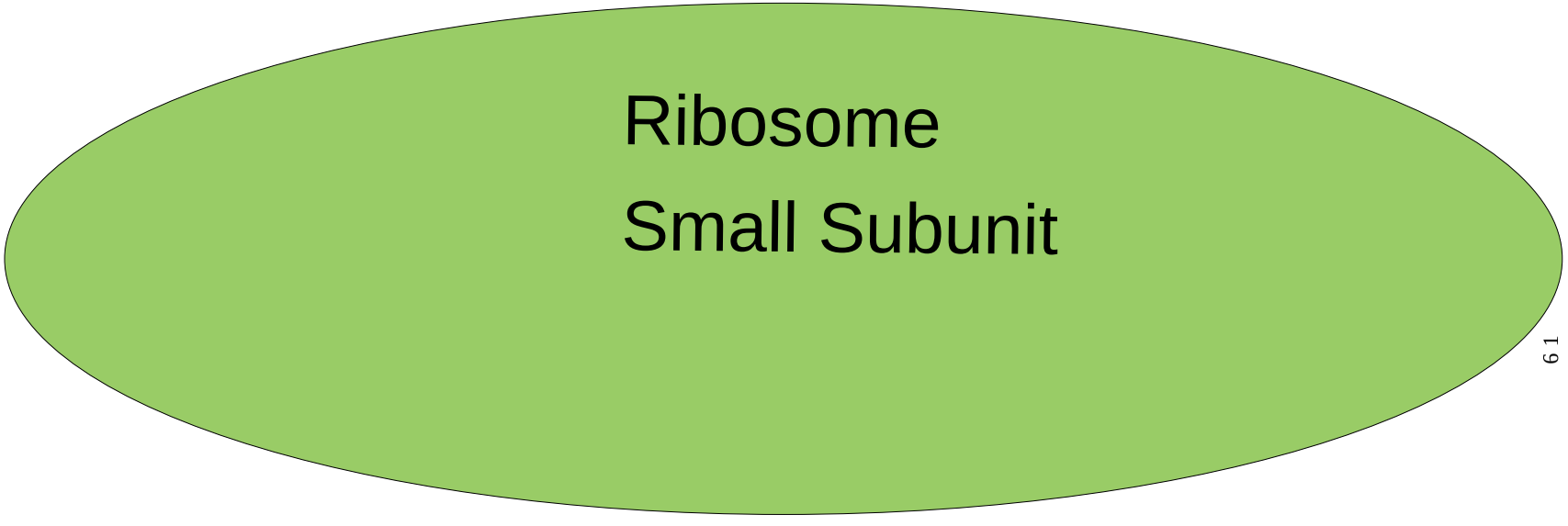
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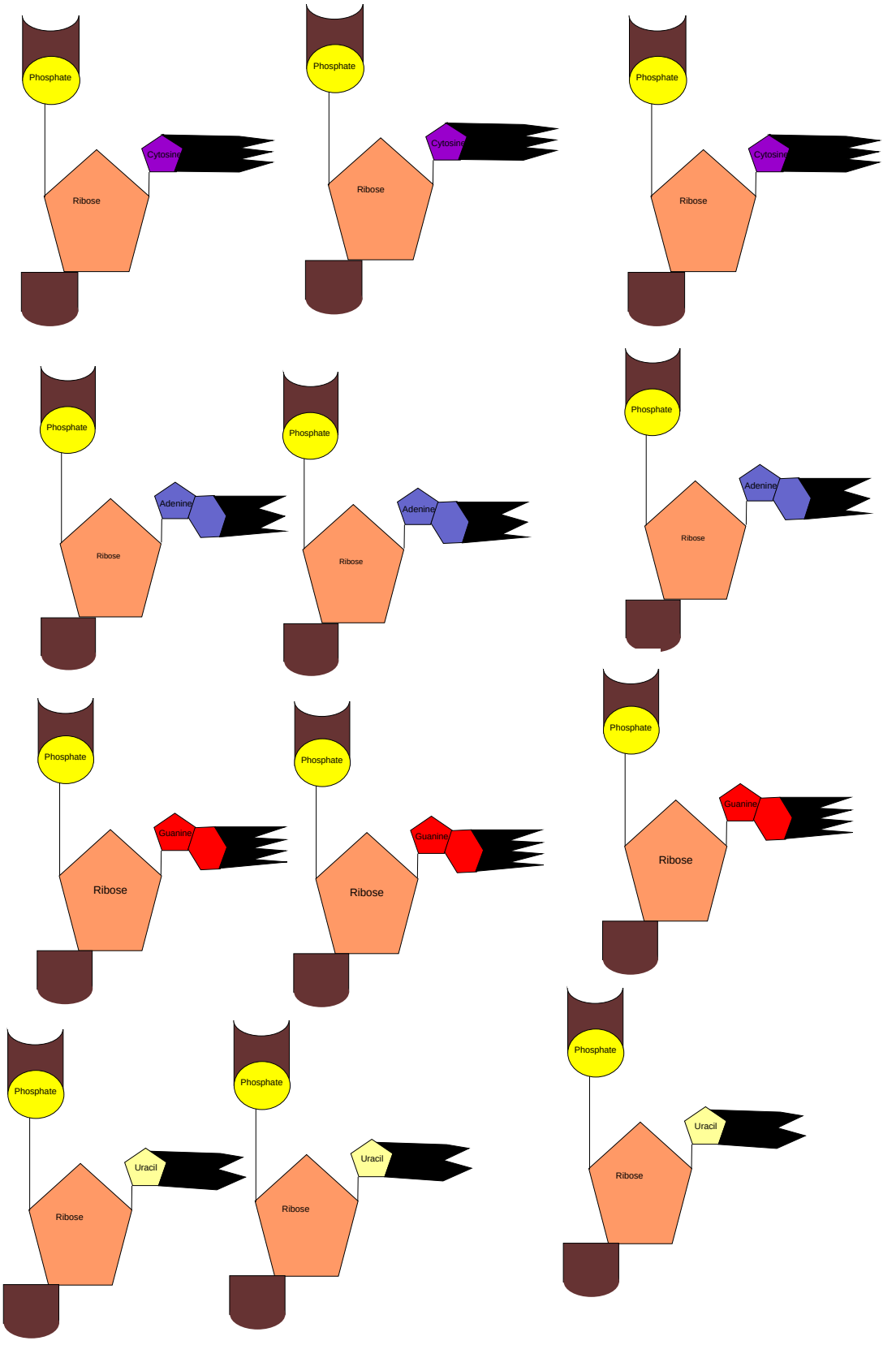
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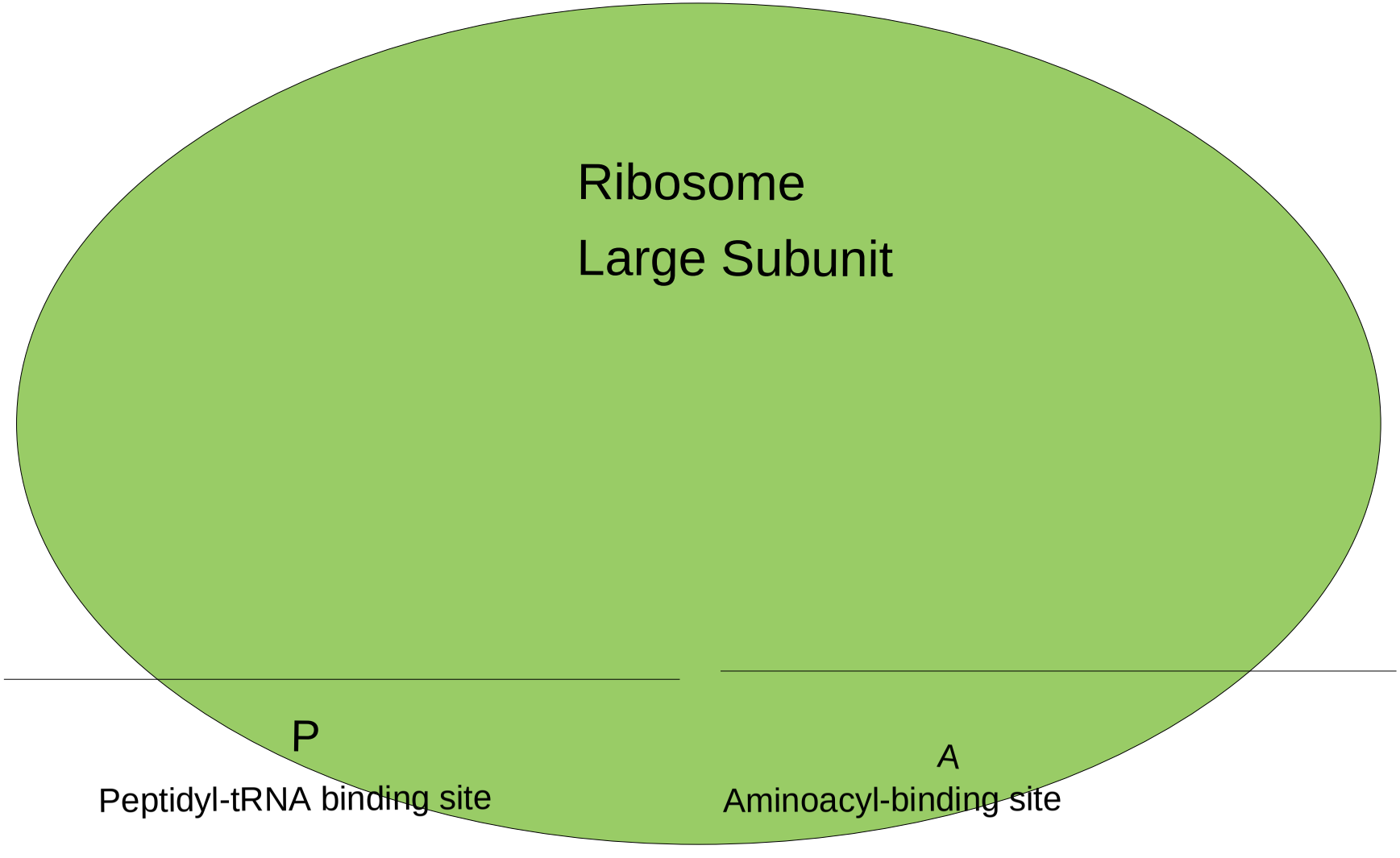
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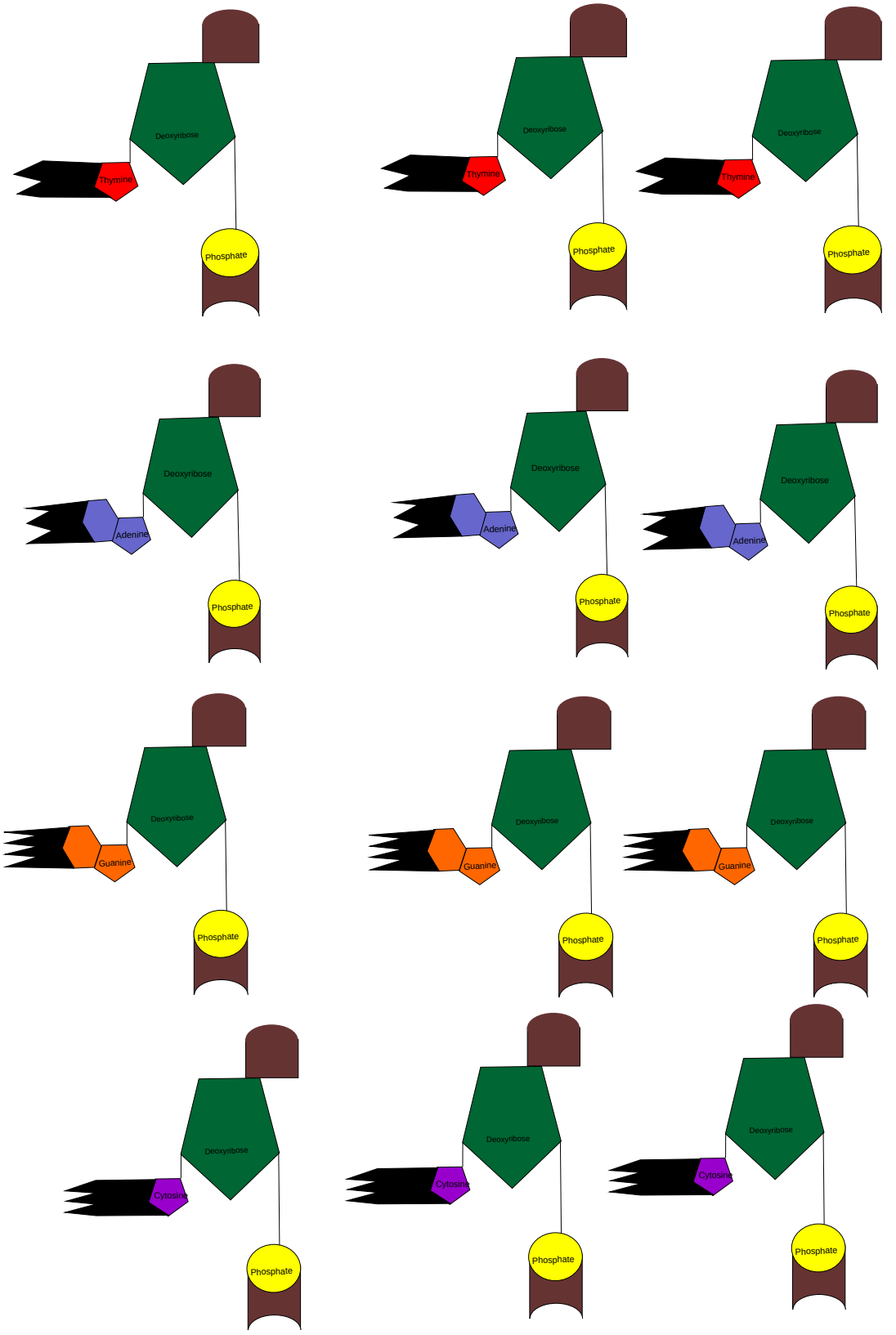
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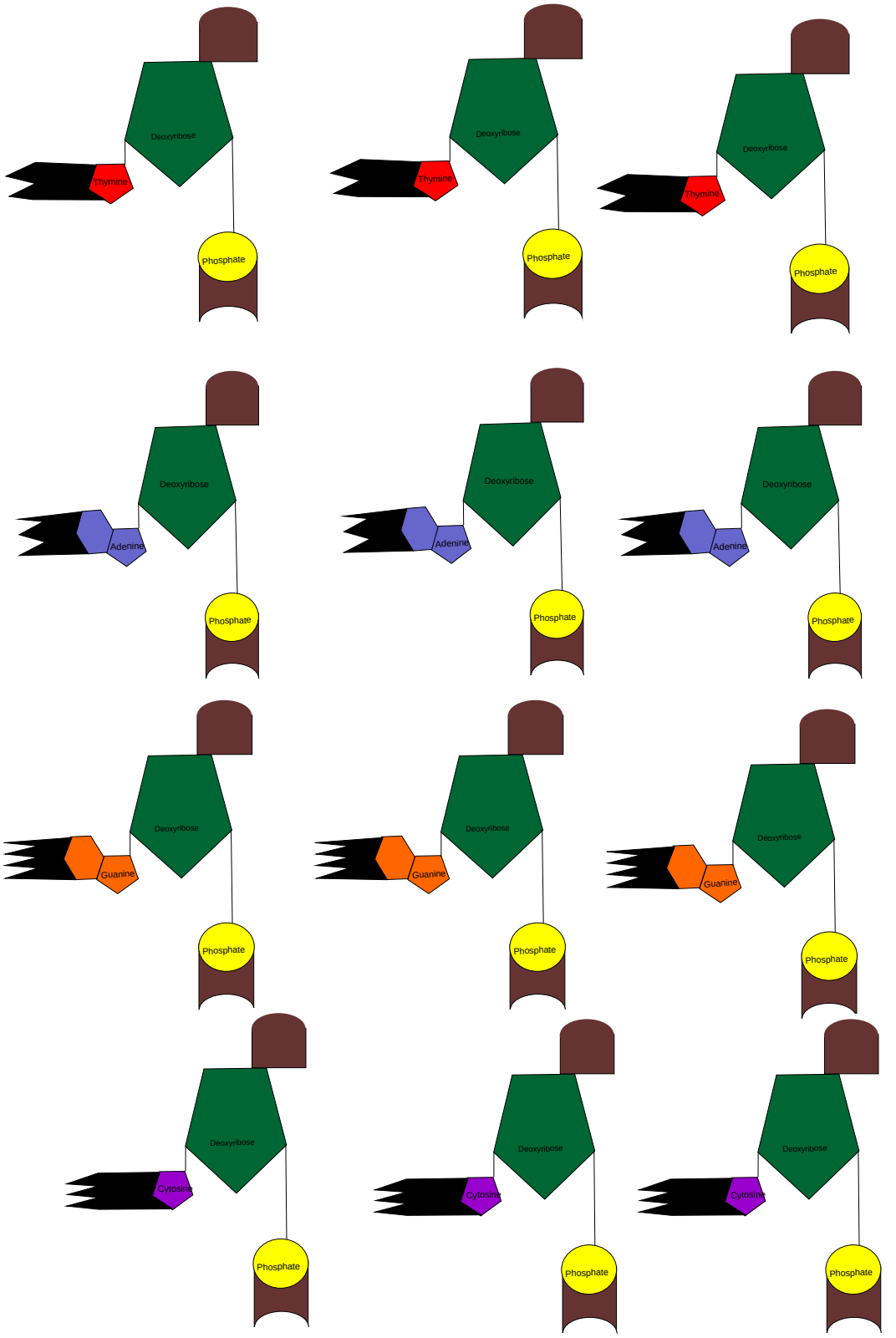
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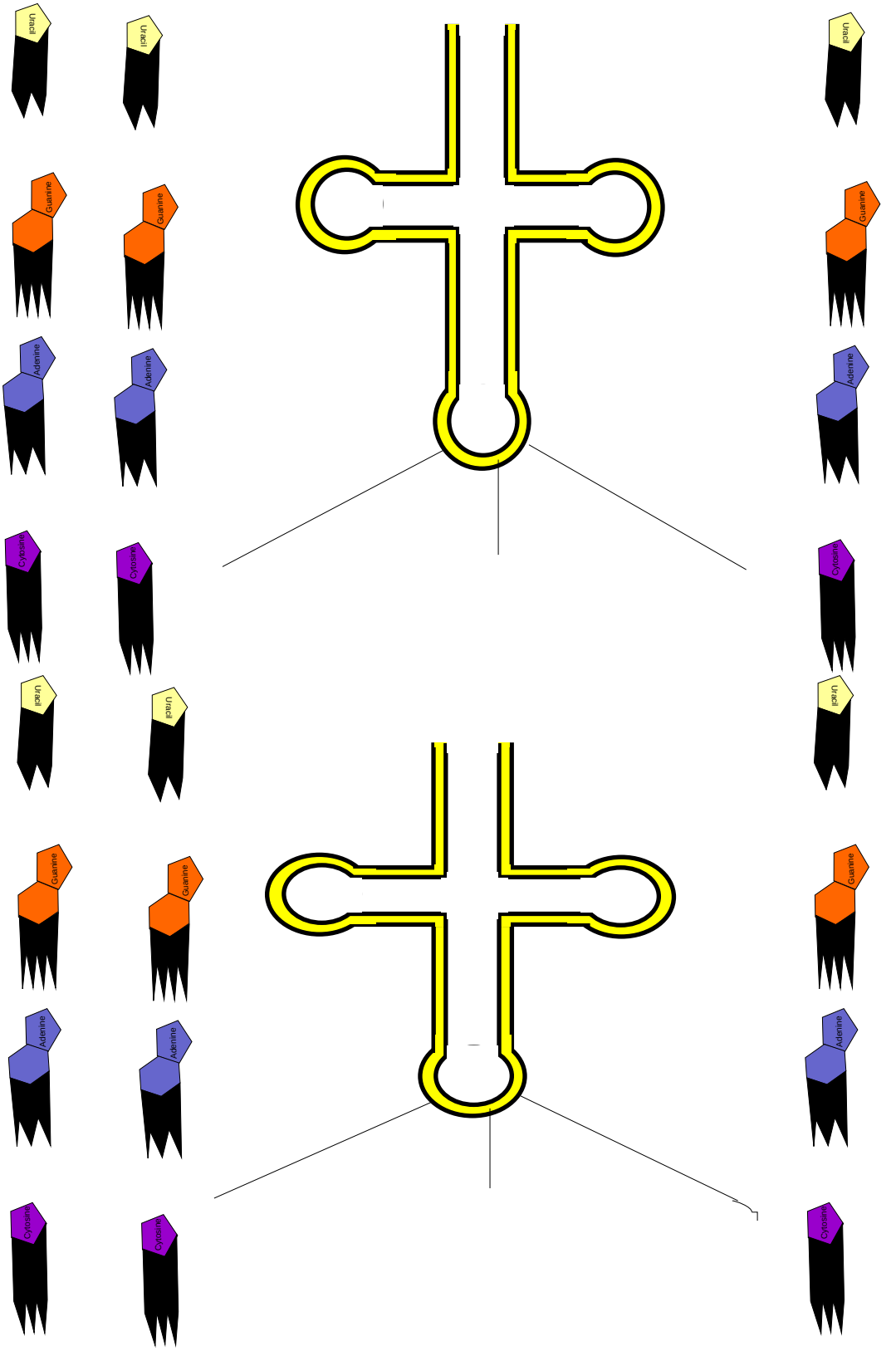
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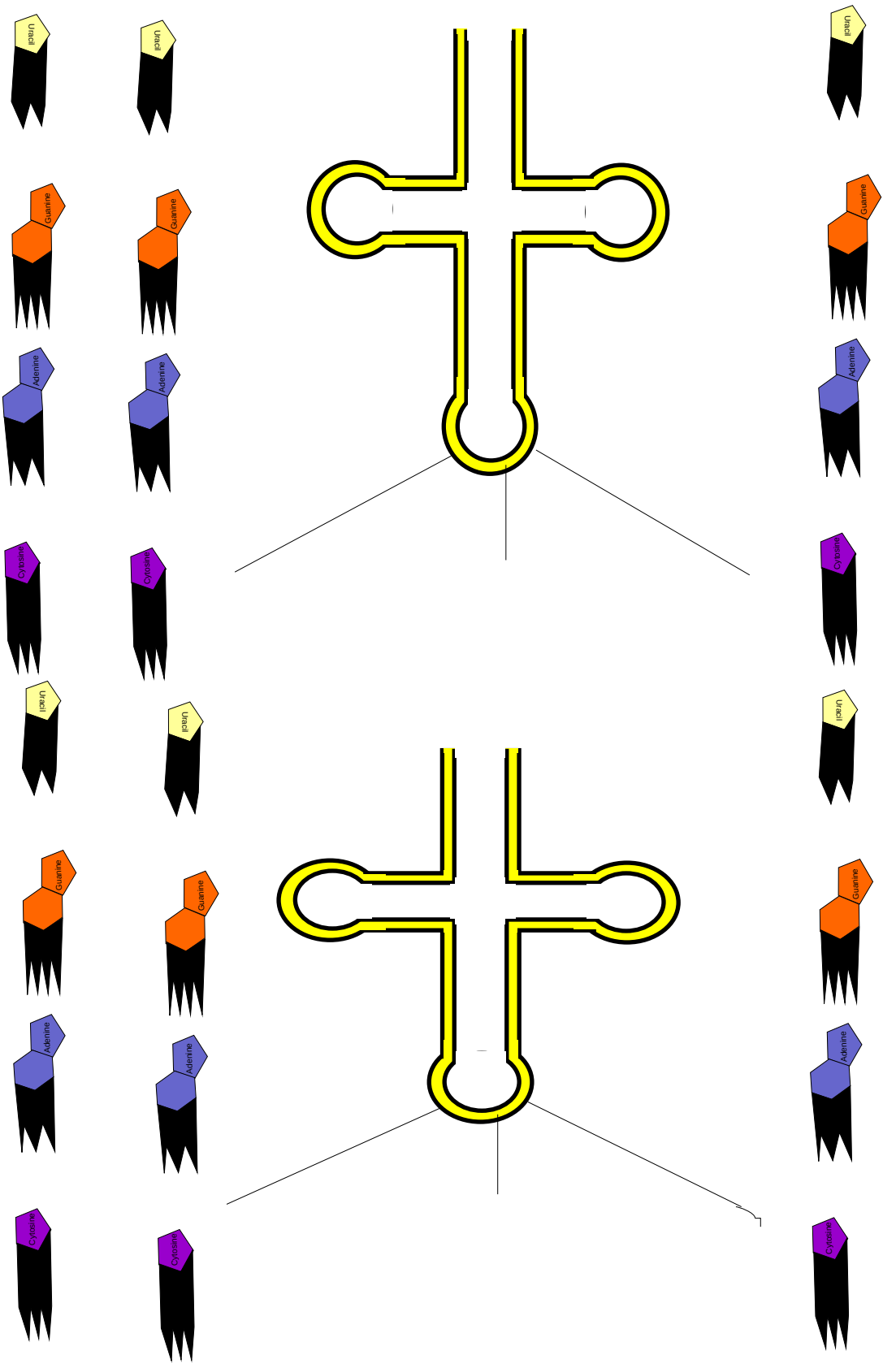
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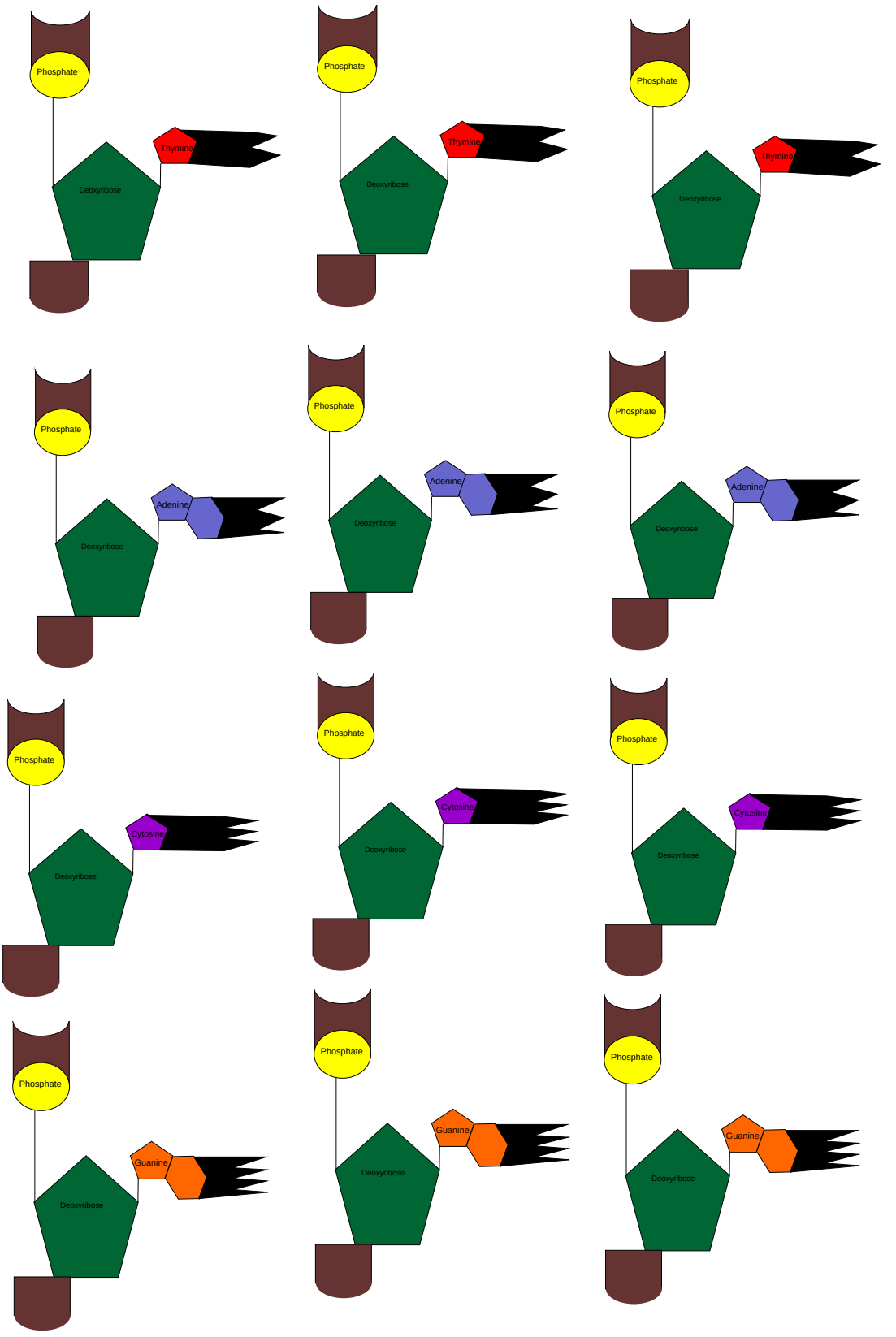
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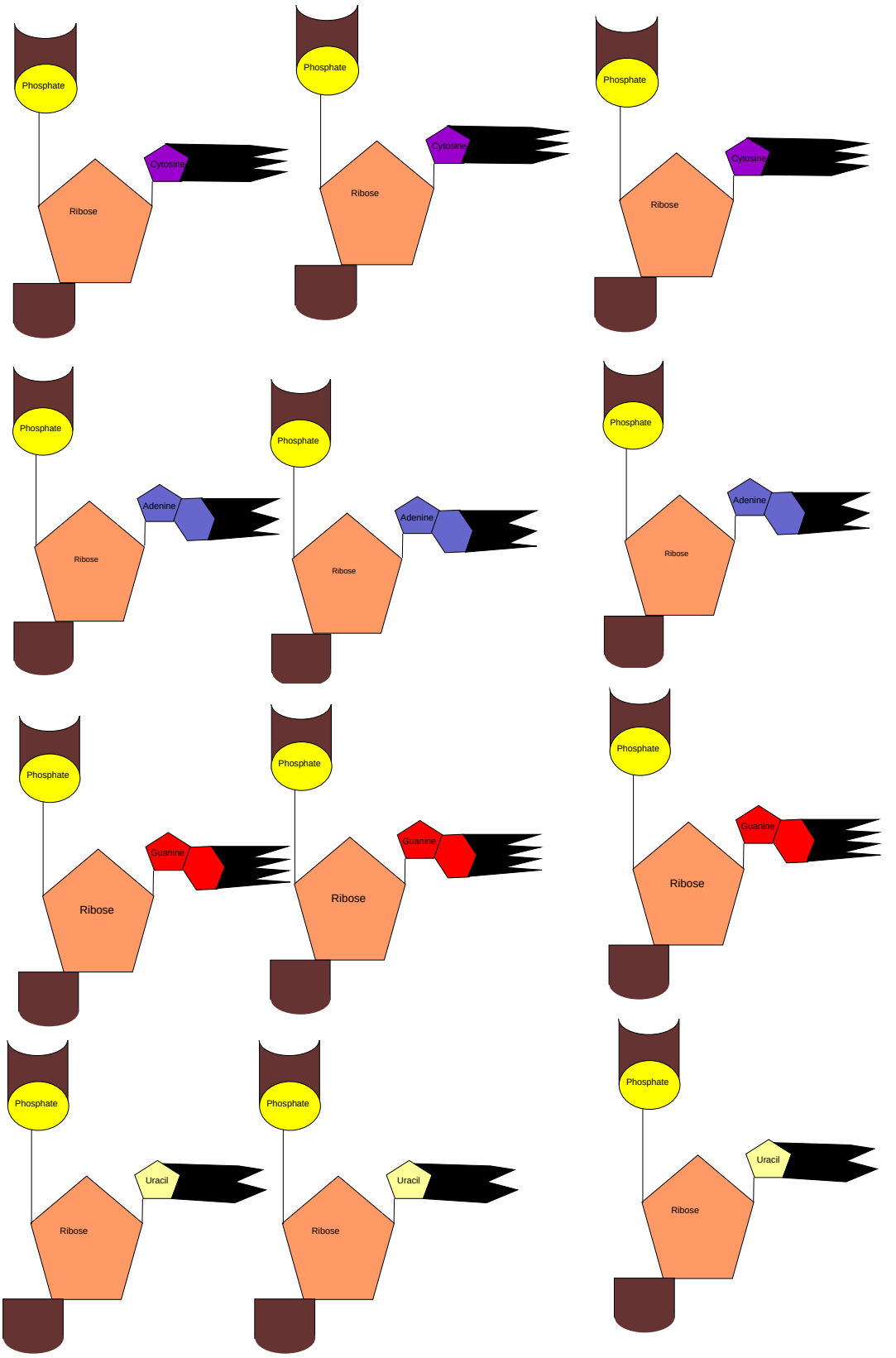
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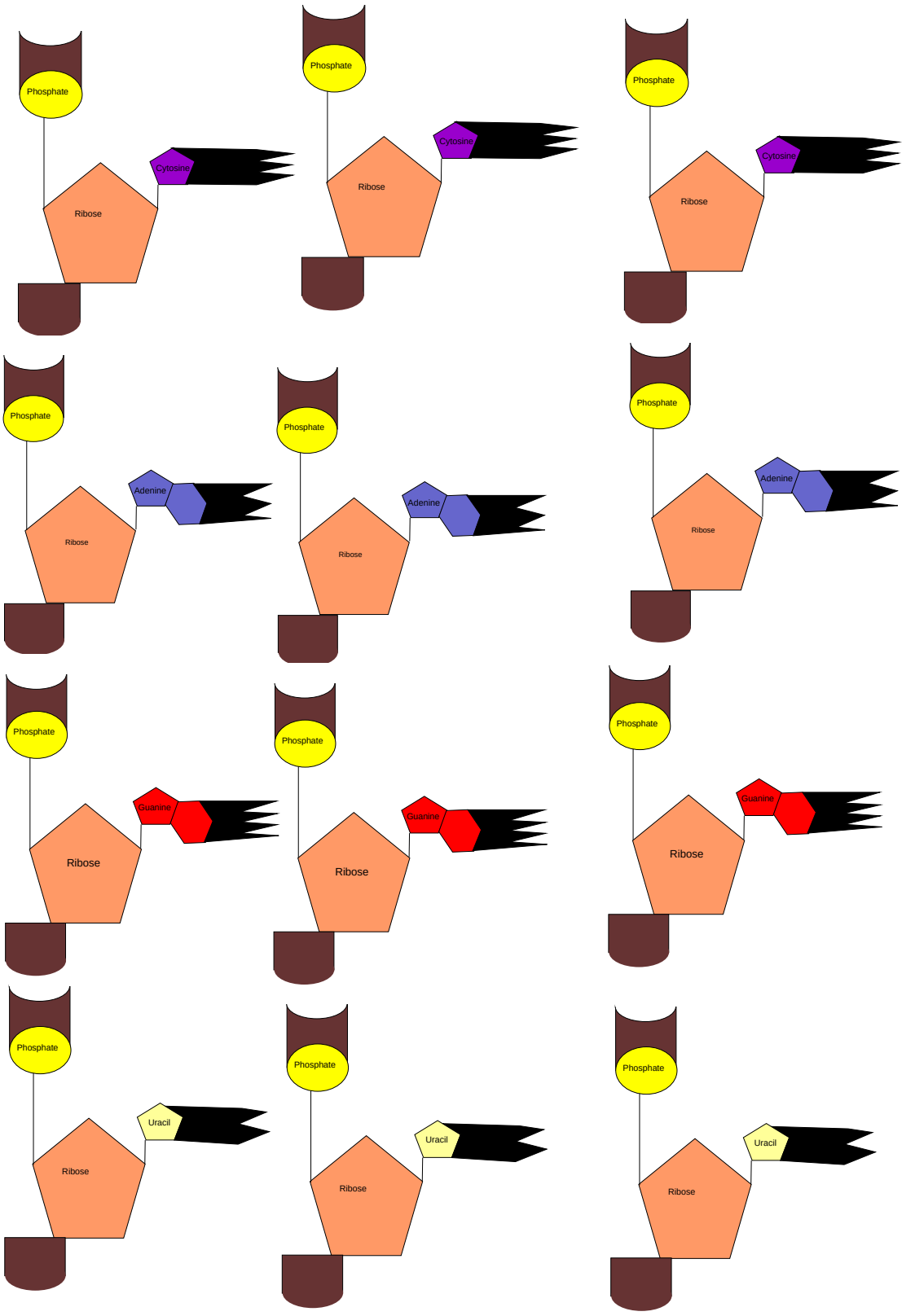
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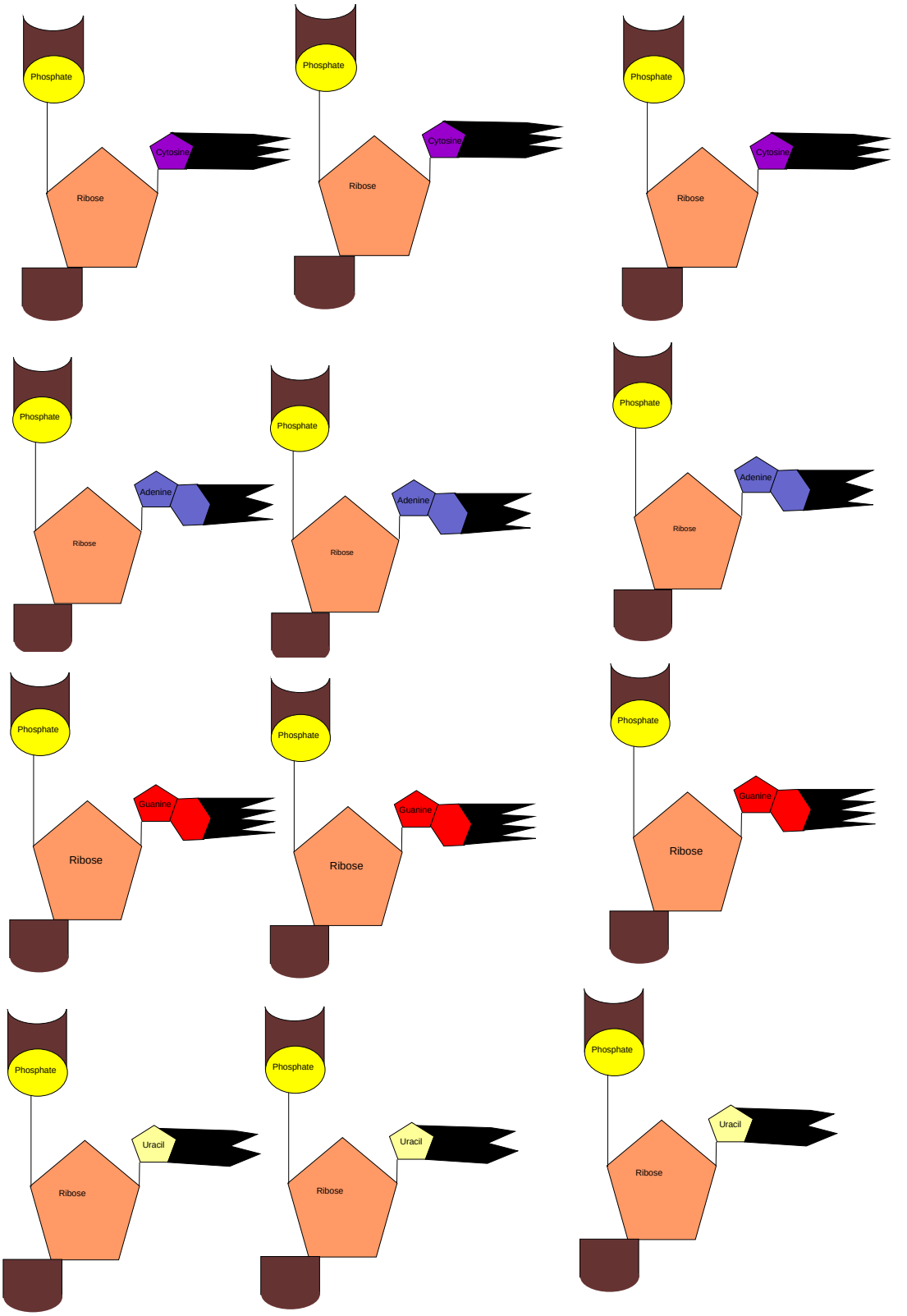
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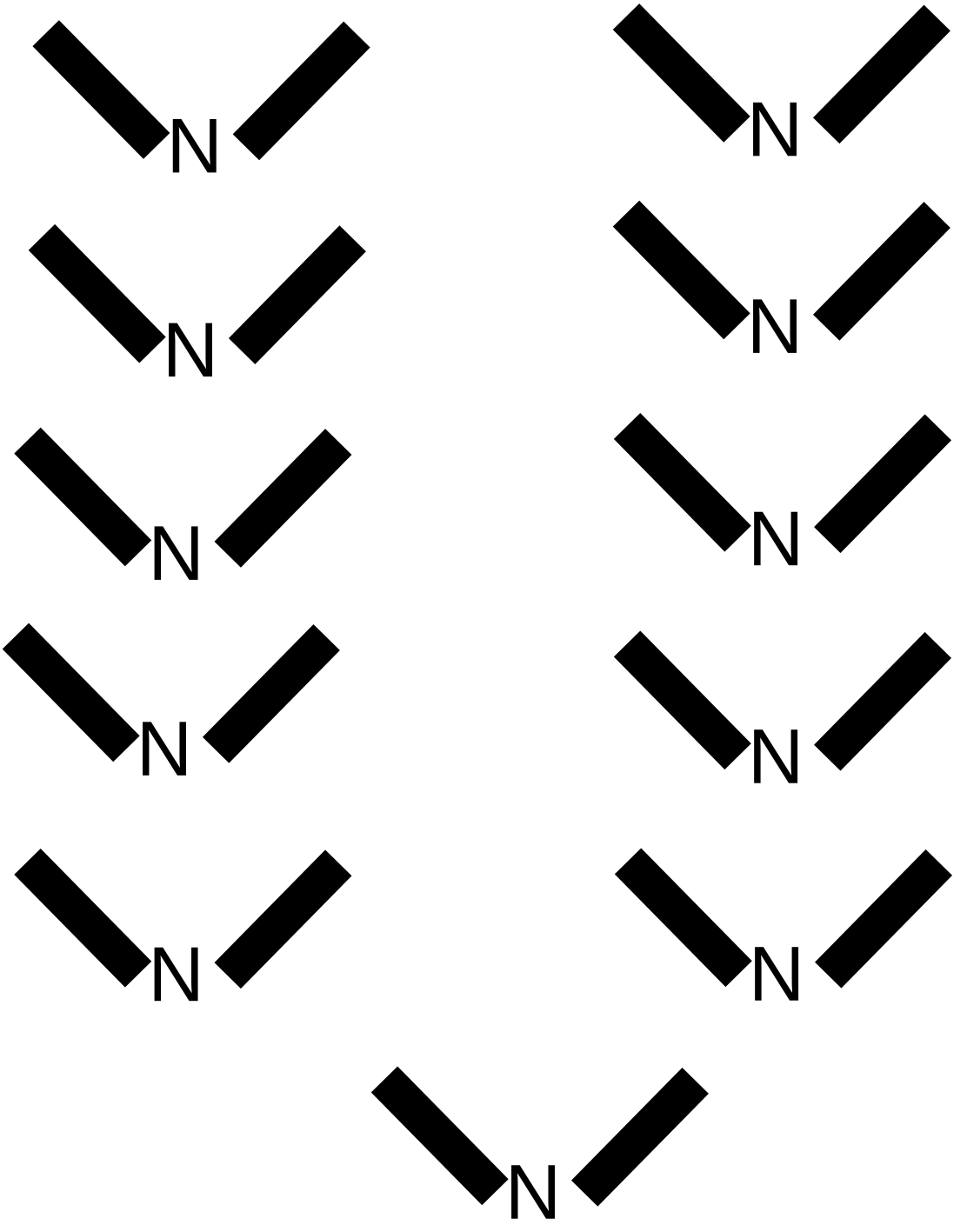

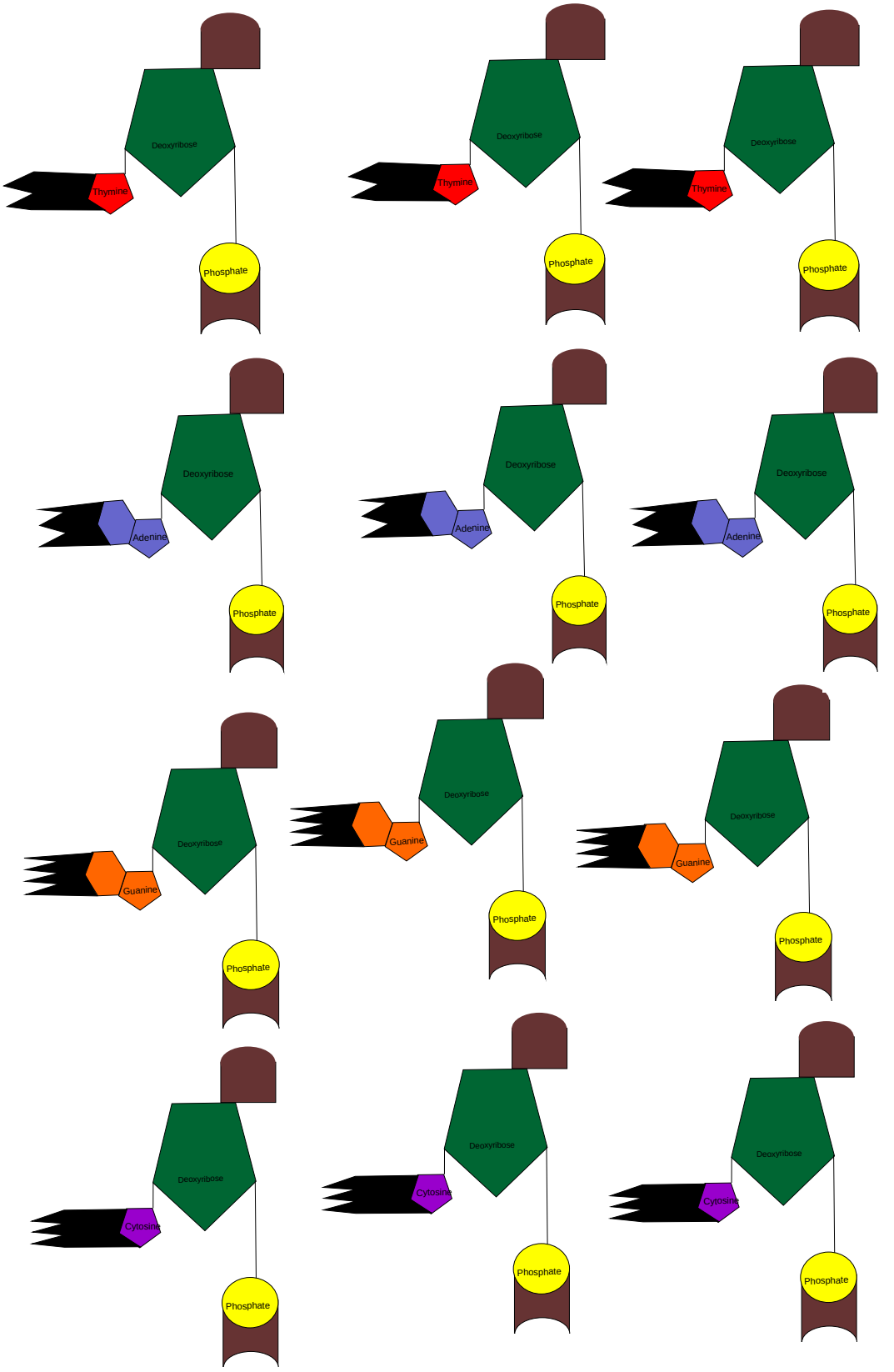
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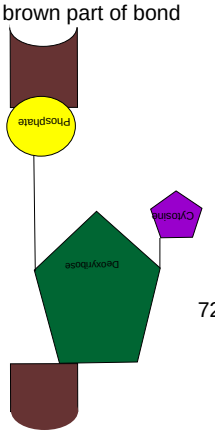
Thymine
Phosphate
Deoxyribose
Thymine
Phosphate
Deoxyribose
Thymine
Phosphate
Deoxyribose
Adenine
Phosphate
Deoxyribose
Adenine
Phosphate
Deoxyribose
Adenine
Phosphate
Deoxyribose
Guanine
Phosphate
Deoxyribose
Guanine
Phosphate
Deoxyribose
Guanine
Phosphate
Deoxyribose
Cytosine
Phosphate
Deoxyribose
Cytosine
Phosphate
Deoxyribose
Cytosine
Phosphate

# Directions for velcro placement and description of parts.

Rough piece under brown part of bond



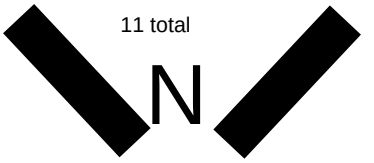

DNA
72 total

Soft piece on white part on top but nor covering brown bond.

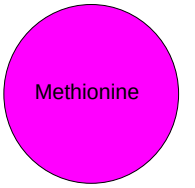
Soft piece on top just above the black line for the bond

Peptide bond

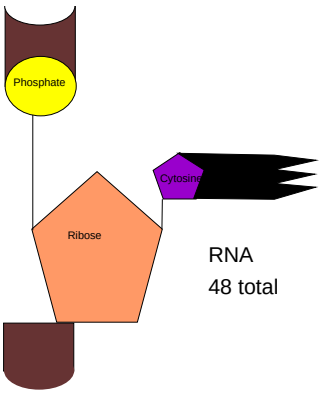
11 total




Rough piece on the bottom in the center of each.
Amino acid - 80 total



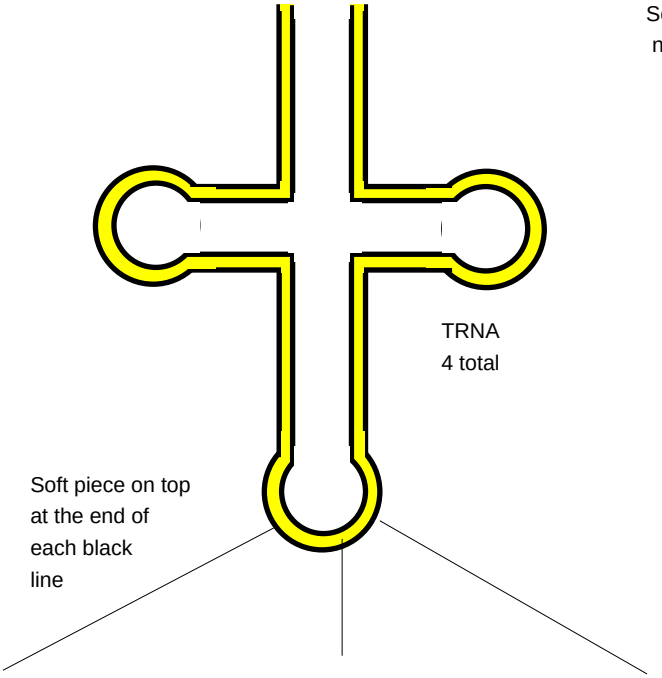

Rough piece under brown part of bond




RNA
48 total

Soft piece on white part on top but nor covering brown bond.

Soft piece on top between the two yellow lines.



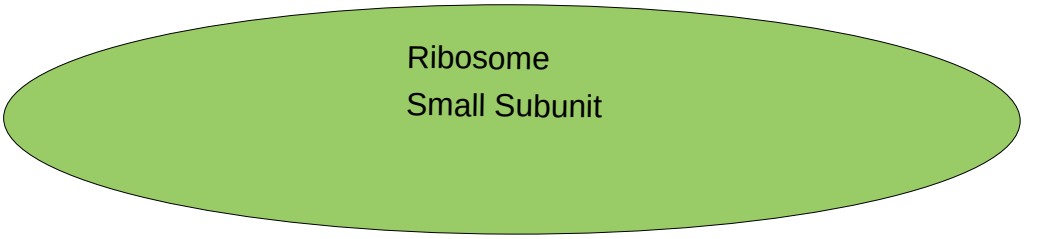
TRNA
4 total

Soft piece on top at the end of each black line

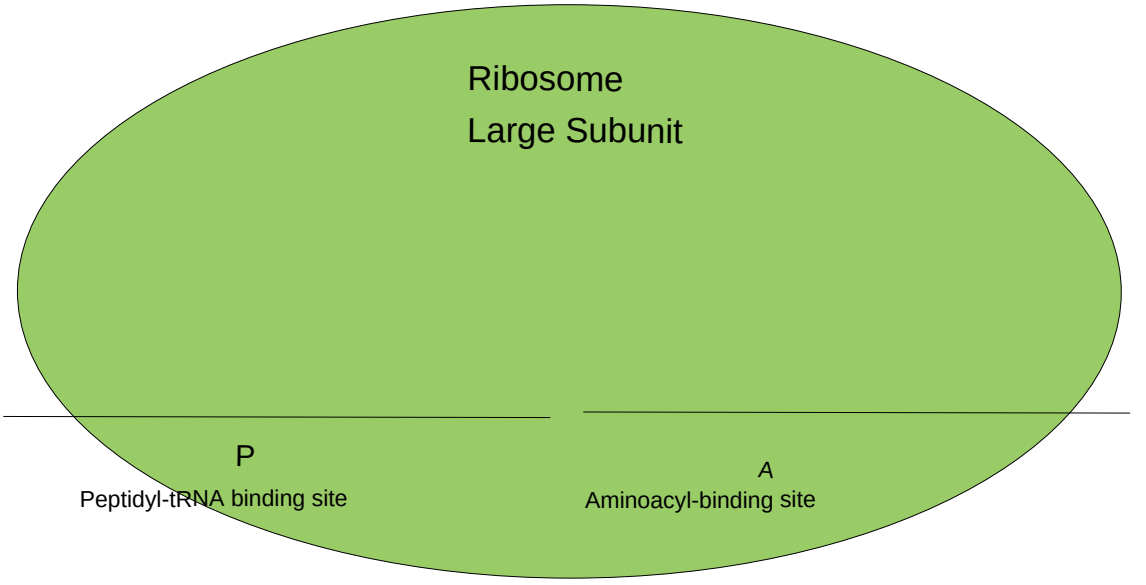
Rough piece on bottom under the nucleotide (colored end)
Loose nucleotide for tRNA - 48 total

# Nucleus

No velcro, to be used to label nuclear area.
1 total




Rough piece on bottom in center just under the label.
1 total




Soft piece in center on top at the very bottom below the names of the binding sites.
1 total

DNA Structure

Using a model and the questions that follow you will learn about the structure of DNA.

Objectives:

1) Students will gain an understanding of the parts of a nucleotide.
2) Students will recognize how the nucleotides bond to make DNA structure.
3) Students will gain understanding of the bonds involved in a DNA molecule.

Materials:

DNA nucleotide pieces of model.

Procedure/Questions:

Remove the DNA nucleotide pieces from their bag. Each individual laminated piece is a nucleotide. Each nucleotide has a phosphate group, a deoxyribose (sugar) and a nitrogen base. Pick out one of each of the four kinds of nucleotides. Use these pieces to answer the questions that follow. Answer the questions in the order they are presented.

1) What can you observe about the pieces? Include a picture of the DNA nucleotides.

2) What parts of the nucleotides are the same for all pieces?

3) What parts of the nucleotides are different for all pieces? How are they different?

4) Thymine and cytosine are grouped together as pyrimidines, while adenine and guanine are grouped together as purines. What is the structural difference between these two groups?

Choose two of the nucleotides you have been observing.

5) Based on your observations, how do these nucleotides appear to bond to each other? Why?

Attempt to bond these nucleotides. If they appear to bond then move on to the next set of questions, if not then try again and ask for help if you need it.

Pick another nucleotide from the two remaining you have been observing.

6) Based on your observations how does this nucleotides appear to bond in a different location and to the other two you just bonded? Why?

Attempt to bond these nucleotides. If they appear to bond then move on to the next set of questions, if not then try again and ask for help if you need it.
Use the fourth nucleotide left from the original four you observed.

7) Based on your observations where could this bond to the other three nucleotides? Why?

Attempt to bond these nucleotides. You should have at least four nucleotides bonded to each other at this point. **Have your teacher check that you have bonded them correctly before moving on.**

8) Draw a picture of the model at this point and describe what has occurred in your own words.

Build a DNA molecule using a total of 10 nucleotides following the ways that nucleotides bond that you just observed.
9) Draw a picture of the model at this point. How would you describe the DNA model? What everyday object does this look similar to?

10) How many bonds (connections or prongs) are there between adenine and thymine?

11) How many bonds (connections or prongs) are there between cytosine and guanine?

The bonds between the nitrogen bases are hydrogen bonds. The bonds between the sugar and the phosphate are covalent bonds. Try to pick up the DNA molecule.

12) Which bonds are weaker and therefore more likely to break?

Conclusions:
1) What three parts always make up a nucleotide?

2) How do the nucleotides differ from each other?

3) How do the nucleotides bond together to make a DNA molecule?

4) Look at three other groups DNA models. Did your DNA model match anyone other groups DNA model?

5) If your model did not match does this mean they or you did it wrong?

DNA Structure Key & Teacher Notes

Using a model and the questions that follow you will learn about the structure of DNA.

Objectives:

1) Students will gain an understanding of the parts of a nucleotide.
2) Students will recognize how the nucleotides bond to make DNA structure.
3) Students will gain understanding of the bonds involved in a DNA molecule.

Materials:

DNA nucleotide pieces of model.

Procedure/Questions: The DNA pieces are the ones with the green deoxyribose. Make sure all students are using theses pieces. Point out to the students that the black and brown parts of the model represent bonds and not molecules. The way that these fit helps to show how the molecules bond to each other. The model is meant to work like a puzzle, with only certain parts able to bond.

Remove the DNA nucleotide pieces from their bag. Each individual laminated piece is a nucleotide. Each nucleotide has a phosphate group, a deoxyribose (sugar) and a nitrogen base. Pick out one of each of the four kinds of nucleotides. Use these pieces to answer the questions that follow. Answer the questions in the order they are presented.

(2)1) What can you observe about the pieces? Include a picture of the DNA nucleotides. Have students observe the similarities and the differences between the nucleotides. Answers will vary. Any observations that fit the actual model is correct. Picture should show the shape of the molecules.

(1) 2) What parts of the nucleotides are the same for all pieces?
The deoxyribose and the phosphate are the same for all pieces

(2) 3) What parts of the nucleotides are different for all pieces? How are they different?
The nitrogen bases are different for each of the four DNA nucleotides. The names are adenine, guanine, thymine and cytosine. The adenine and guanine have two hexagon shapes while the thymine and cytosine have one hexagon. These hexagons represent the carbon-nitrogen chains that make up the purines and pyrimidines.

(1) 4) Thymine and cytosine are grouped together as pyrimidines, while adenine and guanine are grouped together as purines. What is the structural difference between these two groups? Students should be able to recognize that the size of the molecules is different.
Thymine and cytosine have one hexagon shape while the guanine and adenine have two.

Choose two of the nucleotides you have been observing. Be sure that students are only using two of the nucleotides at this point.
(2) 5) Based on your observations, how do these nucleotides appear to bond to each other? Why? Depending on which two nucleotides the students pick to use will depend on which answer they have. Tell them to leave the pieces bonded after this step and add on to this for the next two questions.
Answers will vary but should be one of the following:
1) The two nucleotides can bond between the nitrogen bases because the bonds shown fit like a puzzle.
2) The deoxyribose can bond to the phosphate of the other nucleotide because the bonds fit like a puzzle.
3) The phosphate can bond to the deoxyribose of the other nucleotide because the bonds fit like a puzzle.

Attempt to bond these nucleotides. If they appear to bond then move on to the next set of questions, if not then try again and ask for help if you need it.
Pick another nucleotide from the two remaining you have been observing. Be sure that students only pick up one more nucleotide here. They will bond it to the two they have already bonded. Depending on what they have done and which piece they have picked up will depend on which answer they will have from the three.

(2) 6) Based on your observations how does this nucleotides appear to bond in a different location and to the other two you just bonded? Why? This should be different from the answer they gave for number 5.
Answers will vary but should be one of the following:
1) The two nucleotides can bond between the nitrogen bases because the bonds shown fit like a puzzle.
2) The deoxyribose can bond to the phosphate of the other nucleotide because the bonds fit like a puzzle.
3) The phosphate can bond to the deoxyribose of the other nucleotide because the bonds fit like a puzzle.

Attempt to bond these nucleotides. If they appear to bond then move on to the next set of questions, if not then try again and ask for help if you need it.
Use the fourth nucleotide left from the original four you observed. After bonding this fourth one the students should have a DNA molecule that has four nucleotides with two on each side.
(2)7) Based on your observations where could this bond to the other three nucleotides? Why? This answer should be the different from both questions 5 & 6.
Answers will vary but should be one of the following:
1) The two nucleotides can bond between the nitrogen bases because the bonds shown fit like a puzzle.

2) The deoxyribose can bond to the phosphate of the other nucleotide because the bonds fit like a puzzle.
3) The phosphate can bond to the deoxyribose of the other nucleotide because the bonds fit like a puzzle.

Attempt to bond these nucleotides. You should have at least four nucleotides bonded to each other at this point. **Have your teacher check that you have bonded them correctly before moving on.**

(2) 8) Draw a picture of the model at this point and describe what has occurred in your own words. Students can summarize their drawings if you wish so they do not have to draw out each shape of the nucleotide. They can use the letters to represent the different molecules. You can also point out how the sides of the DNA have stronger bonds than the middle between the nitrogen bases.
Picture should show the four nucleotides bonded with the sugar and phosphates on the sides and the two complimentary pairs bonded in the middle.

Build a DNA molecule using a total of 10 nucleotides following the ways that nucleotides bond that you just observed. This model should have five nucleotides on each side and have the correct complimentary pairing with the sugar and phosphates on the sides..
(3) 9) Draw a picture of the model at this point. How would you describe the DNA model? What everyday object does this look similar to?
Picture should show five nucleotides on each side bonded with complimentary pairs.
The model description may vary but should be along the lines that it has two sides and where things are bonded.
The everyday object it looks like is a ladder.

(1) 10) How many bonds (connections or prongs) are there between adenine and thymine? For this question the students are looking at the black connections between the two nucleotides. These represent the two hydrogen bonds between the two molecules.
2

(1) 11) How many bonds (connections or prongs) are there between cytosine and guanine? For this question the students are looking at the black connections between the two nucleotides. These represent the three hydrogen bonds between the two molecules.
3

The bonds between the nitrogen bases are hydrogen bonds. The bonds between the sugar and the phosphate are covalent bonds. Try to pick up the DNA molecule.
When students try to pick up the DNA the sides should stay together and the middle will come apart since it is not connected with Velcro.

(1) 12) Which bonds are weaker and therefore more likely to break?
The hydrogen bonds between the nucleotides are weaker.

Conclusions:
(1) 1) What three parts always make up a nucleotide?
The three parts to a nucleotide are the phosphate group, the nitrogen base and the sugar

(1) 2) How do the nucleotides differ from each other?
The nucleotides differ at the nitrogen bases. There are four different kinds – adenine, guanine, thymine, and cytosine.

(1) 3) How do the nucleotides bond together to make a DNA molecule?
The nucleotides bond between the nitrogen bases with adenine bonding to thymine and guanine bonding to cytosine and between the deoxyribose and the phosphate.

(1) 4) Look at three other groups DNA models. Did your DNA model match anyone other groups DNA model?
Answers may vary but their model should not match all three.

(1) 5) If your model did not match does this mean they or you did it wrong?
No it just means there are different orders of putting the nucleotides together.

DNA Replication

Using a model and the questions that follow you will learn about the structure of DNA.

Objectives:

1) Students will be able to describe how DNA replication occurs.
2) 2) Students will be able to explain the importance of DNA replication in living things.

Materials:

DNA nucleotides, nuclear membrane string, cell membrane string and nucleus label.

Procedure/Questions:

Answer the following questions in order using the model as required by the questions.

Your drawings do not have to show the shape of the pieces. You may draw using the first letter of the nitrogen bases and a line to show the sugar and phosphate molecules on the side, for example: TAGCT
ATCGA

Build a model of DNA that is 8 nucleotides long. Place the nucleus label where it belongs and use a piece of string to represent the nuclear membrane and the cell membrane.

1) Where are the weaker bonds found in the DNA molecule?

2) What would be the most likely place for the DNA molecule to separate to make a replicate (copy) of the DNA?

3) Is the sequence of the DNA important to living organisms? Why or why not?

4) Draw a picture of the model at this point and in your own words describe it.

Separate the DNA at the point where you feel it is easier and most likely to prevent errors in the DNA sequence. **Have your teacher check your model at this point.**

5) Draw the model at this point and describe what has occurred in your own words.

6) What needs to occur to the DNA now for a copy of the DNA molecule to be made?

Attempt to do the above to your model. If it appears to be making a copy then continue until you have two pieces of identical DNA. If it is not making identical copies alter your answer and try again. **Have your teacher check your DNA molecules at this point.**

7) Draw a picture of the model at this point and describe what has occurred in your own words.

8) What made the DNA molecules identical?

9) Recalling that cells need to divide when the surface area to volume ratio is to small and also for organisms to grow, what do you think the cell would do now that there are two pieces of identical DNA?

Conclusions:

1) What had to happen to the DNA molecule for DNA replication to occur? What molecules were necessary for DNA replication to occur?

2) Why did you separate the DNA molecule at the point you used?

3) Where in the cell does DNA replication take place?

4) What would happen to the amount of cellular DNA when cells divide if DNA replication did not occur?

5) Summarize the process of DNA replication in your own words. A step-by-step picture may be helpful.

DNA Replication Key & Teacher Notes

Using a model and the questions that follow you will learn about the structure of DNA.

Objectives:

1) Students will be able to describe how DNA replication occurs.
2) Students will be able to explain the importance of DNA replication in living things.

Materials:

DNA nucleotides, nuclear membrane string, cell membrane string and nucleus label.

Students only need the green nucleotides, which are the DNA.

Procedure/Questions:

Answer the following questions in order using the model as required by the questions.

Your drawings do not have to show the shape of the pieces. You may draw using the first letter of the nitrogen bases and a line to show the sugar and phosphate molecules on the side, for example: TAGCT
ATCGA

Build a model of DNA that is 8 nucleotides long. Place the nucleus label where it belongs and use a piece of string to represent the nuclear membrane and the cell membrane. The number of nucleotides does not matter and can be longer or shorter. Also the strings may not reach all the way around the DNA. They can be used to show the boundary on one side if necessary. They will occasionally get in the way also so it may be easier to just point out and discuss that this is occurring in the nucleus rather thatn show it with the strings.

(1) 1) Where are the weaker bonds found in the DNA molecule?
The weaker bonds are found between the nitrogen bases. These are hydrogen bonds.

(1) 2) What would be the most likely place for the DNA molecule to separate to make a replicate (copy) of the DNA? Students should think about the importance of keeping the sequence of the DNA in order to answer this question. If the sugar and phosphate were to separate the sequence may be mixed up.
The DNA will separate is the middle between the nitrogen bases.

(2) 3) Is the sequence of the DNA important to living organisms? Why or why not?
Yes. It is what codes for the traits (proteins).

(2) 4) Draw a picture of the model at this point and in your own words describe it. This model is the same as the model made at the end of the DNA structure acitivity.

_____ DNA is in the nucleus and bonded on the sides by covalent
ATACTGTA bonds and in the middle by hydrogen bonds.

**TATGACAT**

Separate the DNA at the point where you feel it is easier and most likely to prevent errors in the DNA sequence. **Have your teacher check your model at this point. Students** should separate the molecule between the nitrogen bases so that the two sides of the DNA have been pulled apart and there is room for the new nucleotides to attach.

(2) 5) Draw the model at this point and describe what has occurred in your own words.

_____ The DNA has separated in the middle at the
ATACTGTA hydrogen bonds.

**TATGACAT**

(1) 6) What needs to occur to the DNA now for a copy of the DNA molecule to be made? Students need to have the bag with the extra nucleotides handy. Teacher should point out that replication means to make a copy of the original so students realize that they need to end up with two of the same molecules. It is also pointed out that the loose nucleotides are available to the molecule in the nucleus.
The loose DNA nucleotides need to bond to the nucleotides that have separated.

Attempt to do the above to your model. If it appears to be making a copy then continue until you have two pieces of identical DNA. If it is not making identical copies alter your answer and try again. **Have your teacher check your DNA molecules at this point.** Students should have two pieces of DNA that are identical to the one they started out with. The teacher may point out that the new pieces are half old and half new since the old was the template and makes up one side of the new DNA.

(2) 7) Draw a picture of the model at this point and describe what has occurred in your own words. The DNA nucleotides have attached to the complimentary nucleotides on the DNA templates to make two exact copies of the DNA.

_____
ATACTGTA
**TATGACAT**

_____
ATACTGTA
**TATGACAT**

(1) 8) What made the DNA molecules identical?
The nucleotides bonding to the complimentary nucleotides on the template.

(1) 9) Recalling that cells need to divide when the surface area to volume ratio is to small and also for organisms to grow, what do you think the cell would do now that there are two pieces of identical DNA? Students that have learned about mitosis and meiosis will have an easier time with this question. For those who have not learned about mitosis and meiosis the teacher needs to remind students that cells divide. Also it should be pointed out that cells will need to have the same information as a cell that divides so it can continue to do the job required.
The cell could now divide so the new cells would have the same DNA.

Conclusions:
(2) 1) What had to happen to the DNA molecule for DNA replication to occur? What molecules were necessary for DNA replication to occur?
The DNA had to separate in the middle and the nucleotides had to attach

(1) 2) Why did you separate the DNA molecule at the point you used?
That is where the weaker bonds are at and it does not disrupt the sequence of the nucleotides.

(1) 3) Where in the cell does DNA replication take place?
DNA replication takes place in the nucleus.

(1) 4) What would happen to the amount of cellular DNA when cells divide if DNA replication did not occur?
If the DNA did not replicate then the new cells would have half the amount of the original DNA.

5) Summarize the process of DNA replication in your own words. A step-by-step picture may be helpful.
DNA separates in the middle where the bonds are weaker and the free nucleotides attach to the complimentary bases on the original DNA to make two new strands.

RNA Structure

Using a model and the questions that follow you will learn about the structure of RNA and how it compares to DNA.

Objectives:

1) Students will be able to compare the nucleotides of DNA to RNA.
2) Students will begin to gain understanding of the role of RNA.

Materials:

DNA and RNA nucleotide pieces of model.

Procedure/Questions:

Remove the RNA nucleotide pieces from their bag. Each nucleotide has a phosphate, a ribose (sugar) and a nitrogen base. Pick out one each of the four different kinds. Use these pieces to answer the questions that follow. Answer the questions in the order they are presented.

1) What can you observe about the RNA nucleotide pieces? Include a picture of a RNA nucleotide.

2) What parts of the nucleotides are the same for all pieces?

3) What parts of the nucleotide are different for all pieces and how do they differ?

Remove one each of the four different DNA nucleotide pieces from their bag.

4) What parts are similar between the DNA and the RNA nucleotides?

5) What parts are different between the DNA and the RNA nucleotides?

6) Do the RNA nitrogen bases look like they could bond with the DNA nitrogen bases? If so how?

RNA Structure Key & Teacher Notes

Using a model and the questions that follow you will learn about the structure of RNA and how it compares to DNA.

Objectives:

1) Students will be able to compare the nucleotides of DNA to RNA.
2) Students will begin to gain understanding of the role of RNA.

Materials:

DNA and RNA nucleotide pieces of model.

Procedure/Questions:

Remove the RNA nucleotide pieces from their bag. Each nucleotide has a phosphate, a ribose (sugar) and a nitrogen base. Pick out one each of the four different kinds. Use these pieces to answer the questions that follow. Answer the questions in the order they are presented. The RNA nucleotides are the orange colored pieces that represent the ribose.

(2) 1) What can you observe about the RNA nucleotide pieces? Include a picture of a RNA nucleotide. Students should point out the similarities and differences that they notice in the four pieces. They may notice similarities and differences between DNA at this point but are not required to do so.
Answers will vary but should include any observations about the RNA nucleotide. The picture should show the shape of the molecules.

(1) 2) What parts of the nucleotides are the same for all pieces?
The parts that are the same are the ribose and the phosphate.

(1) 3) What parts of the nucleotides are different for all pieces and how do they differ?
The parts that are different are the four nitrogen bases – adenine, uracil, guanine and cytosine.

Remove one each of the four different DNA nucleotide pieces from their bag. These are the green deoxyribose sugar pieces.

(1) What parts are similar between the DNA and the RNA nucleotides? Students need to look at the two sets of nucleotides so they are comparing the four nucleotides of each set.
The parts that are similar are the phosphate group, adenine, guanine, and cytosine.

(1) 5) What parts are different between the DNA and the RNA nucleotides?
The parts that are different are the sugars DNA – deoxyribose, RNA – ribose and DNA has thymine while RNA has uracil.

(2) 6) Do the RNA nitrogen bases look like they could bond with the DNA nitrogen bases? If so how? This is leading students toward the process of transcription. The teacher should point out that the RNA sugar and phosphate groups will not bond to the DNA sugar and phosphate groups so students will understand that the bonds between these two need to occur at the nitrogen bases.
Yes they look like they could bond between thymine with adenine, adenine with uracil, guanine with cytosine and cytosine with guanine.

RNA Transcription

Using a model and the following questions you will learn about transcription of RNA.

Objectives:

1) Students will be able to describe the process of transcription.
2) Students will be able to compare and contrast DNA structure to RNA structure.
3) Students will begin to gain an understanding of the role of RNA.

Materials:

DNA and RNA nucleotide pieces, nucleus string, cell membrane string and nucleus label.

Procedure/Questions:

Your drawings do not have to show the shape of the pieces. You may draw using the first letter of the nitrogen bases and a line to show the sugar and phosphate molecules on the side, for example: TAGCT
ATCGA

Remove the DNA nucleotides from the bag. Build a 10 nucleotide long chain of DNA. Place the cell membrane and the nucleus in the correct places on your table. Place the DNA in the correct part of the cell.

1) Which part of the DNA needs to be copied to make an RNA strand that would carry the sequence of the DNA (be a complimentary strand)?

2) How can the sequence of the DNA be made into RNA? (What needs to happen to the DNA molecule first?)

Do what you have just said to your model.

3) Draw a picture of the model at this point and describe what it is showing.

Remove the RNA nucleotides from the bag.

4) Which part of the RNA nucleotides will bond with the DNA nucleotides: the sugar, phosphate or the nitrogen base? (circle one) What are the specific connections that will be made between the DNA nucleotide and the RNA nucleotide?

5) RNA is a single stranded molecule while DNA is double stranded. Do you need to use one side of the DNA or both sides of the DNA to make an RNA molecule.

Attempt to make an RNA molecule from the DNA by making the connections you just described keeping in mind that it is single stranded. **Have your teacher check your model at this point.**

6) Draw a picture of the model at this point and describe what has happened in your own words.

After RNA is made it leaves the nucleus through nuclear pores to carry the DNA information to the rest of the cell.

7) For the RNA to leave the nucleus what must happen to the DNA and the RNA at this point?

Do what you just described to your model. **Have your teacher check your model at this point.**

8) Draw a picture of the model at this point and describe what has occurred in your own words.

9) How does the structure of the RNA molecule compare to the DNA molecule as they now appear? (What is similar and what is different?)

Move your RNA out of the nucleus and into the cytoplasm where it will be used to make proteins for the cell.

10) Draw a picture of the model at this point and describe what has occurred in your own words.

There are actually three types of RNA made by the cell. After the sequence has been copied from the DNA it is modified to become mRNA, tRNA or rRNA.

11) Use your text to describe the shape of these different types of RNA.

Conclusions:

1) Would you be able to make RNA with the correct sequence necessary without DNA?

2) If the DNA has an error from replication would the RNA made from this DNA have the same error?

3) Why does the cell need RNA? What is the purpose of mRNA, tRNA and rRNA?

4) Summarize the process of DNA transcription. A step-by-step picture may be helpful.

RNA Transcription Key & Teacher Notes

Using a model and the following questions you will learn about transcription of RNA.

Objectives:

1) Students will be able to describe the process of transcription.
2) Students will be able to compare and contrast DNA structure to RNA structure.
3) Students will begin to gain an understanding of the role of RNA.

Materials:

DNA and RNA nucleotide pieces, nucleus string, cell membrane string and nucleus label. The students need the orange RNA and the green DNA.

Procedure/Questions:

Your drawings do not have to show the shape of the pieces. You may draw using the first letter of the nitrogen bases and a line to show the sugar and phosphate molecules on the side, for example: TAGCT
ATCGA

Remove the DNA nucleotides from the bag. Build a 10 nucleotide long chain of DNA. Place the cell membrane and the nucleus in the correct places on your table. Place the DNA in the correct part of the cell. This chain of DNA should have ten nucleotides on each side and have the correct complimentary pairing. The strings may be used to show the boundary on one side rather than all the way around the DNA since it may get in the way. Teacher should be sure to point out the DNA is in the nucleus and does not leave the nucleus.

(1) 1) Which part of the DNA needs to be copied to make an RNA strand that would carry the sequence of the DNA (be a complimentary strand)? Teacher should remind students to think about what pat of the DNA is different and can be changed. The students should realize that the nucleotides are what vary and therefore are the code that needs to be copied.

The DNA nucleotide sequence or the nitrogen bases need to be copied.

(1) 2) How can the sequence of the DNA be made into RNA? (What needs to happen to the DNA molecule first?) Teacher can ask students how can a cell get at the DNA code. The students need to realize they need the nucleotide sequence and therefore the DNA needs to separate in the middle like it does for replication so that the code is available to be copied.

The DNA needs to be separated at the middle so the nucleotides can attach.

(2) 3) Draw a picture of the model at this point and describe what it is showing. Have students separate the DNA in the middle before performing this step so that they have the two sides far enough apart that the nucleotides can attach.
Sequence may vary. The DNA molecule has separated in the middle.

_____
ATAGCACAGT

**TATCGTGTCA**

Remove the RNA nucleotides from the bag. These are the orange ribose sugar pieces.

(2) 4) Which part of the RNA nucleotides will bond with the DNA nucleotides: the sugar, phosphate or the nitrogen base? (circle one) What are the specific connections that will be made between the DNA nucleotide and the RNA nucleotide? Students should recall what they have found when looking at RNA structure. By looking at how the black connections on the pieces are they should find that the adenine bonds to the uracil, thymine to adeneine, cytosine to guanine and guanine to cytosine. Students should also recall that the sugar and phosphates of the two different molecules will not attach. The teacher can briefly explain how the enzymes that connect the molecules will not bond the RNA nucleotides to the DNA nucleotides at the sugar and phosphate.
The thymine will bond with adenine, the adenine with uracil, cytosine with guanine and guaninie with cytosine.

5) RNA is a single stranded molecule while DNA is double stranded. Do you need to use one side of the DNA or both sides of the DNA to make an RNA molecule. If students are going to make a one sided molecule they need to realize that they only need to use one side of the DNA. Teacher should point out that this structural difference is one of many other differences between RNA and DNA. Other differences are the DNA having T and RNA having U, the sugars ribose and deoxyribose and also the fact that DNA does not leave the nucleus while RNA can and does.
Only one side of the DNA molecule needs to be used.

Attempt to make an RNA molecule from the DNA by making the connections you just described keeping in mind that it is single stranded. **Have your teacher check your model at this point.** Students should make an RNA molecule from only one side of the DNA and match up the correct complimentary pairs. When finished they should have RNA nucleotides bonded to one side and nothing bonded to the other side.

(2) 6) Draw a picture of the model at this point and describe what has happened in your own words.

Sequence may vary. The RNA nucleotides have bonded with one side of the DNA to make the RNA.

ATAGCACAGT
UAUCGUGUCA

**TATCGTGTCA**

After RNA is made it leaves the nucleus through nuclear pores to carry the DNA information to the rest of the cell.

(1) 7) For the RNA to leave the nucleus what must happen to the DNA and the RNA at this point? Students need to recall that the DNA does not leave the nucleus so if the RNA does it would need to detach from the side of DNA that served as the template. After this has occurred they should see that the DNA needs to go back together to keep the sequence protected and keep from making more RNA.

The RNA needs to detach from the DNA and move out of the middle so the DNA can go back together.

Do what you just described to your model. **Have your teacher check your model at this point.** Model should now have the DNA put back together and still in the nucleus while the single stranded RNA has separated from the DNA but not moved out of the nucleus yet. It can be discussed at this point how the RNA that is made is modified as it leaves the nucleus so it does not stay the same as what is copied directly from the DNA.

8) Draw a picture of the model at this point and describe what has occurred in your own words.

ATAGCACAGT UAUCGUGUCA The RNA has detached and moved out of the way so the DNA went back together.
TATCGTGTCA

(1) 9) How does the structure of the RNA molecule compare to the DNA molecule as they now appear? (What is similar and what is different?) Students should be able to recognize all the differences between the RNA and DNA that were mentioned earlier.

The DNA is double stranded and the RNA is single stranded. The nitrogen bases A, G and C are the same while DNA has T and RNA has U. The sugars are different.

Move your RNA out of the nucleus and into the cytoplasm where it will be used to make proteins for the cell. Students' models will be similar to what they just had except now the RNA is outside the nucleus in the cytoplasm.

10) Draw a picture of the model at this point and describe what has occurred in your own words.

ATAGCACAGT
TATCGTGTCA

UAUCGUGUCA

The DNA has remained in the nucleus and RNA has moved out into the cytoplasm.

There are actually three types of RNA made by the cell. After the sequence has been copied from the DNA it is modified to become mRNA, tRNA or rRNA. It should be pointed out that these are all made from the DNA and that the RNA is modified before it leaves the nucleus to become the specific type of RNA.

(3) 11) Use your text to describe the shape of these different types of RNA.
mRNA- a single stranded sequence of nucleotides
tRNA – a hairpin or clover shaped sequence of nucleotides
rRNA – a globular shape of nucleotides

Conclusions:
(1) 1) Would you be able to make RNA with the correct sequence necessary without DNA?
No, the DNA is the sequence that determines how RNA should be put together.

(1) 2) If the DNA has an error from replication would the RNA made from this DNA have the same error?
Yes because the RNA is made directly from the DNA.

(3) 3) Why does the cell need RNA? What is the purpose of mRNA, tRNA and rRNA?
The cell needs RNA to carry the DNA information to the rest of the cell.

The mRNA carries the codon sequence for the protein synthesis, tRNA carries the anticodon to bond to the mRNA and the amino acids, the rRNA helps to bond the mRNA and the tRNA in the ribosome.
(2) 4) Summarize the process of DNA transcription. A step-by-step picture may be helpful.
1) The DNA separates in the middle between the nitrogen bases at the hydrogen bonds.

2) The RNA nucleotides attach to the DNA using only one side as a template.
3) The RNA detaches from the DNA and the DNA goes back together.
4) The RNA leaves the nucleus for the cytoplasm.

# Translation

You will use a model and the following questions to learn about the process of translation.

Objectives:

1) Students will gain an understanding of the process of translation.
2) Students will be able to explain how DNA is used for making proteins.
3) Students will recognize how a mutation can affect the translation process.

Materials:

RNA nucleotides, amino acids, tRNA, loose nucleotides, string for nuclear membrane, string for cell membrane, two pieces of the ribosome, peptide bonds.

Review Questions: Answer these questions before moving on to use the model and performing translation.

1) Recalling what you learned about cell parts, what is the role of the ribosome in the cell? (What organic compound does it help to make?)

2) Recalling what you learned about organic compounds what is the monomer of the molecule you answered for question 2?

3) What are the three types of RNA and the function of each? How will they be used in the process of translation?

4) How many nucleotides make up a codon, what is it used to code for and where is it found?

5) How many nucleotides make up an anticodon, what is it used for and where is it found?

Procedure/Questions:

Remove the RNA nucleotides from the bag and build a 21 nucleotide long chain of mRNA. Build the model from left to right so the first nitrogen base is pointing upwards. The side of the RNA should start with a phosphate that is not bonded to

anything and the ribose end bonding to the phosphate of the next nucleotide. **The first three letters must be AUG, the last three letters must be one of the following: UAA, UAG, or UGA, and the rest of the order does not matter.**
1) Where would the mRNA you just made be found in the cell?

Find the two pieces of the ribosome. Notice that the ribosome has two binding sites on it. There are actually three binding sites but space would not allow for the third site, which is the exit site, to be shown. The A site signals what codon is on the mRNA for the tRNA to bond to. The P site signals for the peptide bond to form between the two amino acids presently in the ribosome on the tRNA at that site to detach from its amino acid.

Put the two pieces of the ribosome together and place the ribosome so that the first three nucleotides (codon) are in the A binding site.

Remove the tRNA and loose nucleotides from the bag. Each tRNA needs three nucleotides at the end of it to make the anticodon.

2) How can you determine what the anticodon will be? Where do you think the anticodon of the tRNA will bond?

Using a tRNA card place the correct anticodon on the bottom of the tRNA for it to bond with the first codon of the mRNA.

Each amino acid has a specific codon. Use the codon chart provided to determine which amino acid the codon AUG codes for. Attach this amino acid to the top of the tRNA with the correct anticodon attached. These twenty amino acids are obtained by the diet (eight) and made by the body (twelve). **Have your teacher check you model at this point.**

3) Draw a picture of the model at this point and describe in your own words what has occurred.

4) Recalling what the A site is for what do you think would need to happen to the ribosome for the next tRNA to bond to the mRNA?

Attempt to do this and make the tRNA necessary with the correct anticodon and amino acid attached to it. If it doesn't seem to work revise and try again. Ask for help if you need it.

7) Draw what your model looks like at this point and describe what has occurred in your own words.

Amino acids bond to each other by peptide bonds. Bond the two amino acids on your model to each other using one of the peptide bonds provided. Recall what happens at the P site. Remember that the amino acid only detaches from the mRNA at the P site. This means that the amino acid in the A site is bonded with a peptide bond to the other amino acid and still bonded to its tRNA.

8) What do you think would need to happen for the next tRNA to come in and bond to the mRNA?

Attempt to do what you think needs to happen. **Have your teacher check your model at this point.**

9) Draw your model and describe what has occurred in your own words.

Continue translating the mRNA until you reach the end. A stop codon does not have an amino acid to attach to the tRNA with the matching anticodon. This is what causes the polypeptide chain to stop being made.

10) Draw a picture of the model at this point and describe what has occurred.

11) What do you think would occur if the cell needed more of the protein made by this mRNA?

12) What do you think would occur if the cell did not need more of the protein made by this mRNA?

The next part of the investigation looks at what occurs when there is a mutation in the code.

Set aside the amino acid chain you made from the first translation.

In the mRNA change the fourth nucleotide to a different letter. This represents a mutation having occurred.

13) What could have caused the mutation to occur?

Perform the process of translation like you did the first time.

14) How does your amino acid chain compare to the amino acid chain you made the first time?

Conclusions:

1) Where did the sequence for the RNA originally come from?

2) Where do the amino acids come from that are used in translation?

3) Why must the first three letters be AUG and the last three one of the following UAA, UAG, or UGA?

4) What is necessary for translation to take place?

5) Summarize the process of translation in your own words.  A picture may be helpful.

6) How would a mutation affect an organism?

7) Is a mutation in the DNA more of a problem or a mutation in the RNA?  Why?

Translation Key & Teacher Notes

You will use a model and the following questions to learn about the process of translation.

Objectives:

1) Students will gain an understanding of the process of translation.
2) Students will be able to explain how DNA is used for making proteins.
3) Students will recognize how a mutation can affect the translation process.

Materials:

RNA nucleotides, amino acids colored circles with names in middle, tRNA 4 yellow loops, loose nucleotides small rectangular individual nucleotide, string for nuclear membrane, string for cell membrane, two pieces of the ribosome 2 large green pieces, peptide bonds black ----N----. Students will use all pieces except the green DNA nucleotides.

Review Questions: Answer these questions before moving on to use the model and performing translation. These questions help students to recall what the parts of translation are and what the functions are that they know of so far. Students may use their text to answer or do as a class discussion.

(1) 1) Recalling what you learned about cell parts, what is the role of the ribosome in the cell? (What organic compound does it help to make?)
The ribosome is the location of protein synthesis.

(1) 2) Recalling what you learned about organic compounds what is the monomer of the molecule you answered for question 2? This is asking for the monomer of proteins.
The monomer is amino acids.

(3) 3) What are the three types of RNA and the function of each? How will they be used in the process of translation? Students need to use their textbook or lecture notes to answer the function of the RNAs
mRNA- carries the DNA sequence out of the nucleus to the ribosome to put the amino acids in the correct order

tRNA – carries the amino acids to the ribosome and bonds with the codon to put amino acids in correct order
rRNA – contained in the ribosome and helps to put the mRNA together with the tRNA

(2) 4) How many nucleotides make up a codon, what is it used to code for and where is it found? Students need to have had a lecture/discussion on this or use their text to answer. They also need to be able to use a chart that provides the names of the amino acids for specific codons.
Three nucleotides make up a codon, which is the code for the amino acids and is found on the mRNA.

(2) 5) How many nucleotides make up an anticodon, what is it used for and where is it found? Students need to have had a lecture/discussion or use their textbook to answer this.
Three nucleotides make up the anticodon,

Procedure/Questions:

Remove the RNA nucleotides (the orange colored ribose) from the bag and build a 21 nucleotide long chain of mRNA. Build the model from left to right so the first nitrogen base is pointing upwards. The side of the RNA should start with a phosphate that is not bonded to anything and the ribose end bonding to the phosphate of the next nucleotide. **The first three letters must be AUG, the last three letters must be one of the following: UAA, UAG, or UGA, and the rest of the order does not matter.** The mRNA needs the start codon to be first and then a stop codon to be the last three so the process can stop. The mRNA should be made so that the AUG will fit into the A site of the ribosome with the black bonds pointing towards the top of the ribosome so the tRNA can bond to it.
(1) 1) Where would the mRNA you just made be found in the cell?
The mRNA would be found in the cytoplasm.

Find the two pieces of the ribosome the two large green ovals. Notice that the ribosome has two binding sites on it. There are actually three binding sites but space would not allow for the third site, which is the exit site, to be shown. The A site signals what codon is on the mRNA for the tRNA to bond to. The P site signals for the peptide bond to form between the two amino acids presently in the ribosome on the tRNA at that site to detach from its amino acid.

Put the two pieces of the ribosome together and place the ribosome so that the first three nucleotides (codon) are in the A binding site. The mRNA AUG should be lying on the line of the A site in the ribosome.

Remove the tRNA yellow loops and loose nucleotides small rectangular pieces with black bonds for bonding to nucleotides from the bag. Each tRNA needs three nucleotides at the end of it to make the anticodon. Stress that the tRNA is made by the cell in a different process.

(2) 2) How can you determine what the anticodon will be? Where do you think the anticodon of the tRNA will bond? The students should recall that the tRNA needs to bond to the mRNA and therefore the anticodon will be complimentary to the codon on the mRNA.
It is complimentary to the codon and will bond to the codon on the mRNA.

Using a tRNA card place the correct anticodon on the bottom of the tRNA for it to bond with the first codon of the mRNA. Students should use the loose nucleotides to place the nucleotides UAC on the three pieces of Velcro at the bottom.

Each amino acid has a specific codon. Use the codon chart provided to determine which amino acid the codon AUG codes for. Students should find that methionine is the amino acid that is coded for Attach this amino acid to the top of the tRNA with the correct anticodon attached. These twenty amino acids are obtained by the diet (eight) and made by the body (twelve). Students should put the bright pink circle that says methionine at the top of the tRNA. They should then bond this tRNA to the mRNA. **Have your teacher check you model at this point.** The model should show the mRNA with the AUG codon in the A site and the tRNA with the UAC anticodon and methionine bonded to it attached to the AUG codon.

(2) 3) Draw a picture of the model at this point and describe in your own words what has occurred. The ribosome has attached to the mRNA and the corresponding tRNA has bonded to the mRNA with its correct amino acid.

(1) 4) Recalling what the A site is for what do you think would need to happen to the ribosome for the next tRNA to bond to the mRNA? Students can be reminded that this is where the tRNA comes in to bond to the mRNA so they should realize that the ribosome needs to move over so the next codon is available.
The ribosome will need to move over so that the next codon on the mRNA is available for a tRNA in the A site.

Attempt to do this and make the tRNA necessary with the correct anticodon and amino acid attached to it. If it doesn't seem to work revise and try again. Ask for help if you need it. Students will need to make another tRNA with the correct anticodon on the bottom and the amino acid that the codon from the mRNA codes for on the top. This tRNA will then bond to the mRNA codon now in the A site. Remind students that the tRNA are made in a separate process. Include this concept in discussion also.

(2) 7) Draw what your model looks like at this point and describe what has occurred in your own words.
The ribosome has slid over so that the next tRNA came in and bonded to the mRNA with the proper codon and anticodon matched. The tRNA has the correct amino acid on it.

Amino acids bond to each other by peptide bonds. Bond the two amino acids on your model to each other using one of the peptide bonds ----N---- provided. Recall what happens at the P site. Remember that the amino acid only detaches from the mRNA at the P site. This means that the amino acid in the A site is bonded with a peptide bond to the other amino acid and still bonded to its tRNA. Students should recall that at the P site the peptide bonds are formed.

(1) 8) What do you think would need to happen for the next tRNA to come in and bond to the mRNA? The ribosome needs to slide over but students need to realize that the amino acids need to bond by the peptide bond before this can occur. To show the peptide bond students need to remove the amino acid from the tRNA in the P site and place it on one end of the peptide bond. The other end of the peptide bond connects to the amino acid that remains connected to its tRNA in the A site. After the peptide bond has formed the ribosome will slide over and the tRNA that was in the P site will leave without an amino acid attached. The tRNA in the A site will move to the P site and a new tRNA will come in.
The amino acids will bond to each other with a peptide bond and the first tRNA will leave the ribosome. The ribosome will need to slide over again so a new mRNA is available for the next tRNA.

Attempt to do what you think needs to happen. **Have your teacher check your model at this point.** The model should show what was just described so that the first amino acid is peptide bonded to the second and the AUG is now outside the ribosome with the second tRNA in the P site and a third tRNA in the A site. Students need to make the third tRNA in the same fashion they made the second. The anticodon is attached along with the correct amino acid.

(2) 9) Draw your model and describe what has occurred in your own words.
The first amino acid has bonded to the second amino acid by a peptide bond and the first tRNA has left the ribosome. The third tRNA is now in the ribosome along with the second, which is still bonded with its amino acid.

Continue translating the mRNA until you reach the end. A stop codon does not have an amino acid to attach to the tRNA with the matching anticodon. This is what causes the polypeptide chain to stop being made. Students would now make the peptide bond between the second amino acid and the amino acid on the third tRNA in the A site. The ribosome would move over so the second tRNA will leave and the third tRNA is now in the P site. This would continue until they reach the seventh codon, which should be a stop codon, so no amino acid and the polypeptide chain is six amino acids long.

(2) 10) Draw a picture of the model at this point and describe what has occurred.
The ribosome has continued to move along the mRNA and new tRNAs have bonded with the mRNA to bring in the amino acids which have been bonding by peptide bonds to form a polypeptide chain. Once it reached a stop codon then there was no amino acid to bond and the polypeptide was finished.

(1) 11) What do you think would occur if the cell needed more of the protein made by this mRNA? Students should realize that more ribosomes can attach once the AUG is free from the ribosome so many ribosomes can be on the same mRNA at one time.
More ribosomes would attach if more of the same protein were needed.

(1) 12) What do you think would occur if the cell did not need more of the protein made by this mRNA? Students should think about the fact that as long as the mRNA is present it will make polypeptides.
The cell would stop translation and break down the mRNA.

The next part of the investigation looks at what occurs when there is a mutation in the code.

Set aside the amino acid chain you made from the first translation. Students need to keep the polypeptide made the first time to compare to the one made when a mutation occurs.

In the mRNA change the fourth nucleotide to a different letter. This represents a mutation having occurred. Students can change any letter as long as it is different form the one they currently have. By changing this letter it should code for a different amino acid since very few have codons that vary at this point and still code for the same amino acid.

(1) 13) What could have caused the mutation to occur? Students should be familiar with antigens. Asking about things that may cause cancer since some cancers are caused by mutations can prompt them.
A mutagen such as cigarette smoke or UV rays could have caused the mutation.

Perform the process of translation like you did the first time. Students use the mRNA with the mutation and go through the whole process of making another polypeptide chain. They then compare this chain to the chain made from the original mRNA they saved.

(1) 14) How does your amino acid chain compare to the amino acid chain you made the first time?
Answers will vary. Most should have a different amino acid where the mutation occurred. Some may have a shortened polypeptide if a stop codon were created at that point.

Discuss what would happen if the mutation were to occur in different places such as the start codon, stop codon, or other places along the mRNA.

Conclusions:

(1) 1) Where did the sequence for the RNA originally come from?
The sequence for the RNA is from the DNA made during transcription.

(1) 2) Where do the amino acids come from that are used in translation?
The amino acids come from our diet and are produced by the body to be used in translation.

(1) 3) Why must the first three letters be AUG and the last three one of the following UAA, UAG, or UGA? The first three letters must be AUG since that is the start codon and the last three are the stop codons.

(1) 4) What is necessary for translation to take place?
For translation to occur a cell needs mRNA, tRNA, and rRNA and also a ribosome. Also amino acids may be mentioned.

(2) 5) Summarize the process of translation in your own words. A picture may be helpful.
A ribosome attaches to the mRNA at the AUG and a tRNA with a complimentary anticodon comes in to bond to the mRNA. This tRNA brings the correct amino acid with it. The ribosome moves over for the next codon to receive its tRNA with corresponding amino acid. The amino acids bond to each other using a peptide bond. The ribosome continues to move along the mRNA and tRNAs continue to bond and their amino acids which continue to bond using peptide bonds. The process stops when it reaches a stop codon and the polypeptide can leave to do its job.

(1) 6) How would a mutation affect an organism?
A mutation will change the sequence of the mRNA and therefore change what amino acid is being coded for and also the protein being made.

(2) 7) Is a mutation in the DNA more of a problem or a mutation in the RNA? Why?
A mutation in the DNA would be permanent since the DNA is never broken down so this would be more of a problem since all RNA made from the DNA would have the mutation. A mutation in the RNA would only affect the cell for as long as that RNA was used to make proteins.

Review Activity

Use the model and the directions below to review what you have learned throughout this unit.

Objectives:

2) Students will be able to revisit the concepts taught over the time of the unit and perform and explain them on their own.

Materials:

Entire DNA/RNA model kit

Procedure/Questions:

Build a DNA molecule that is 12 nucleotides long and place it in the correct location using the nuclear membrane string and the cell membrane string.

1) Draw the model and describe the types of bonding that are involved and also what parts of the nucleotides bond to each other.

Perform the process of DNA replication.

2) Draw the steps involved in the process and describe what is occurring at each step.

Use one strand of the DNA made by replication and perform the process of transcription.

3) Draw the steps involved in transcription and describe each step in detail.

Use the mRNA made by transcription and perform the process of translation.

4) Draw the steps involved in translation and describe each step in detail.

Conclusions:

1) Where is DNA found? Include in the cell and types of cells.

2) Why is DNA replication necessary to survival and where does it occur?

3) How does DNA structurally compare to RNA?

4) How does DNA functionally compare to RNA?

5) Why is transcription necessary for survival and where does it occur?

6) Why is translation necessary for survival and where does it occur?

7. If the DNA triplet is TAC what is the complimentary mRNA code?

8) If the mRNA codons are AUG, GGU, CAG what anticodons on the tRNA will attach?

9) What amino acids will be attached to the tRNA mentioned above in question 8?

10) What is the source of free amino acids in the cytoplasm?

11) If the DNA analysis shows 20% adenine bases, what would be the percentage of thymine?_____ cytosine?_____ guanine?_____ and

uracil?_____

12) What are two general uses of protein in an organism?

13) What might be the result of a mutation of DNA in which a triplet code such as CAC now say CTC?

14) Summarize the steps involved in a DNA sequence becoming a protein.

Review Activity Key & Teacher Notes

Use the model and the directions below to review what you have learned throughout this unit.

Objectives:

3) Students will be able to revisit the concepts taught over the time of the unit and perform and explain them on their own.

Materials:

Entire DNA/RNA model kit

Procedure/Questions:

Build a DNA molecule that is 12 nucleotides long and place it in the correct location using the nuclear membrane string and the cell membrane string. Length of DNA can vary. Students will use this DNA to perform replication.

Each of the drawing questions are three points – One for drawing and two for description.

1) Draw the model and describe the types of bonding that are involved and also what parts of the nucleotides bond to each other.

Pictures should show the correct bonding and the DNA in the nucleus.

The hydrogen bonds are found between the complimentary nitrogen bases and the covalent bonds are found between the deoxyribose and the phosphate.

The adenine bonds to thymine, guanine to cytosine and the deoxyribose to the phosphate.

Perform the process of DNA replication.

2) Draw the steps involved in the process and describe what is occurring at each step.

Pictures should show correct bonding and each step involved.

Steps:

1) DNA separates in the middle between the nitrogen bases.
2) DNA nucleotides bond to the templates of the original DNA.
3) There are two exact copies of the DNA made.

Use one strand of the DNA made by replication and perform the process of transcription. After replication remind students that the cell would divide to make two identical cells. Have students set one of the DNA molecules they have made aside for transcription and put the other one away since it is in a different cell now. Students then use the DNA molecule to perform transcription.

3) Draw the steps involved in transcription and describe each step in detail.
Pictures should show the correct steps
Steps:
1) DNA separates in the middle between the nitrogen bases.
2) RNA nucleotides attach to only one side of the DNA that is the template.
3) After the RNA is copied it detaches from the DNA and the DNA sides go back together.
4) The RNA leaves the nucleus.

Use the mRNA made by transcription and perform the process of translation.
Students should set the DNA aside so it is out of the way since they are working outside the nucleus for translation. They should use the RNA made by transcription to make a polypeptide.

4) Draw the steps involved in translation and describe each step in detail.
Pictures should show each step and be accurate.
Steps:
1) The ribosome attaches to the mRNA at the AUG, which is the start codon.
2) The tRNa with the anticodon moves in to ribosome and bonds to the mRNA.
3) The ribosome slides over so the next codon is ready for a tRNA, which comes in and bonds to the mRNA.
4) The amino acids on the tRNAs bond with a peptide bond.
5) The ribosome slides over to the next codon and the first tRNA leaves to get another amino acid. The next tRNa comes in to bond to the mRNA codon.
6) Process continues until it reaches a stop codon.

Conclusions:

1) Where is DNA found? Include in the cell and types of cells.

DNA is found in the nucleus and found in all cells.

2) Why is DNA replication necessary to survival and where does it occur?

DNA replication is necessary so all cells have the same DNA in an organism. It occurs in the nucleus.

3) How does DNA structurally compare to RNA?

DNA is double stranded while RNA is single stranded, DNA has thymine while RNA has uracil, and DNA has deoxyribose while RNA has ribose.

4) How does DNA functionally compare to RNA?

DNA is the blueprint meaning it carries the information for making proteins. RNA is made from the DNA and carries out the protein synthesis.

5) Why is transcription necessary for survival and where does it occur?

Transcription makes the RNA from the DNA so the information on the DNA can leave the nucleus to allow proteins to be made. This occurs in the nucleus.

6) Why is translation necessary for survival and where does it occur?

Translation connects the amino acids in the correct sequence using RNA as the template. The amino acids are modified into the proteins the body uses. This occurs in the cytoplasm on the ribosome.

7) If the DNA triplet is TAC what is the complimentary mRNA code?

The mRNA would be AUG.

8) If the mRNA codons are AUG, GGU, CAG what anticodons on the tRNA will attach?

The tRNA would be UAC, CCA, GUC.

9) What amino acids will be attached to the tRNA mentioned above in question 8?

The amino acids would be tyrosine, proline, and valine.

10) What is the source of free amino acids in the cytoplasm?

The amino acids come from our diet and the body makes some of them.

11) If the DNA analysis shows 20% adenine bases, what would be the percentage of thymine?____20%_____ cytosine?_____30%_____ guanine?_____30%_____ and

uracil?_____0%_____

12) What are two general uses of protein in an organism?
Proteins are used as the building material and for enzymes.

13) What might be the result of a mutation of DNA in which a triplet code such as CAC now say CTC?
The mRNA made from this DNA would have the same mutation and therefore the codon would be changed so it would code for a different amino acid, which would then change the protein.

14) Summarize the steps involved in a DNA sequence becoming a protein.
The answer should summarize the entire process from DNA replication to translation.

# Appendix E

## Outline for Discussion and Lecture

Unit VI. DNA

Chapters 10 & 13

**A. Structure of DNA**

1) Made of neuclotides –
   a) 4 nitrogen bases - 2 purines (adenine & guanine) & 2 pyrimidines (thymine & cytosine)
   b) a phosphate group
   c) five carbon sugar – deoxyribose
2) Watson & Crick described as long thin spiral helix
3) Amount of G=C and A=T
4) Sugar and phosphate on sides w/ nitrogen bases bonded in center
5) Sequence of nucleotides is code for protein synthesis

**B. DNA Replication**

1) Occurs before cell division
2) Chemical bonds connecting bases break and separates in middle forming replication fork
3) Proper nucleotides pair w/ complimentary nucleotide on strands
4) Original strand is template
5) Powered by ATP
6) Accuracy & repair
   a) change in one nucleotide can cause a mutation
   b) 1 in 1 billion nucleotides since enzymes proofread
   c) can be damaged by mutagens

**C. DNA & RNA**

1) DNA –blueprint, doesn't leave nucleus
2) RNA –carries out protein synthesis,
   a) differences from DNA – ribose, uracil instead of thymine & single stranded
   b) types –
      mRNA – carries sequence,
      tRNA – transfer amino acids,
      rRNA- helps connect tRNA & mRNA

**D. Transcription**

1) Copies RNA from DNA
2) Process
   a) DNA separates in middle
   b) one side is template where RNA nucleotides attach
   c) as RNA made and detaches from DNA, the DNA reattaches itself
   d) continues until termination signal
   e) mRNA leaves nucleus

**3) Sequence of mRNA is code for amino acids that make proteins**

4) Code is three letters – codon
5) 20 amino acids – 64 codons

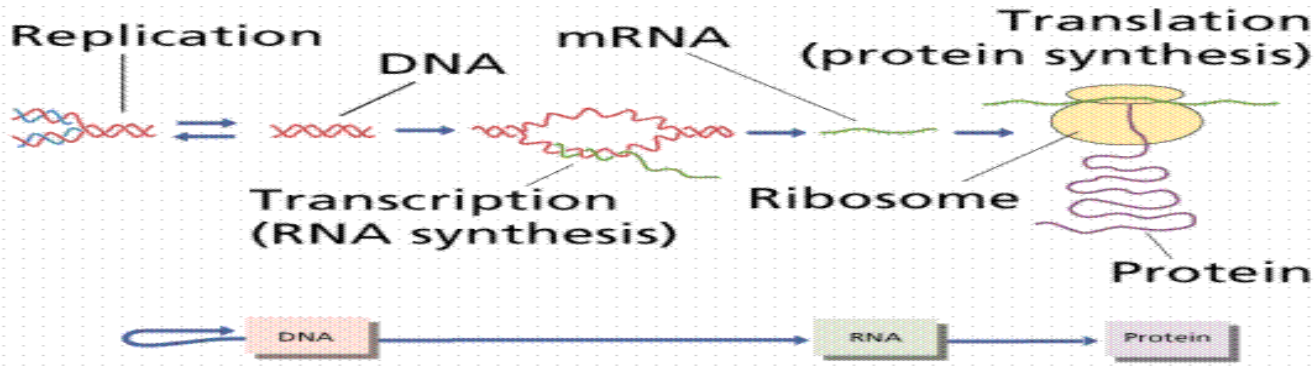
6) AUG – methionine – start codon
7) Three stop codons

**Go over Codon Chart**

**E. Translation**

1)Makes proteins from mRNA
2) Part needed
   a) ribosomes – larger part has enzymes that link amino acids
   b) tRNA – amino acids on one end, has anticodon to attach to mRNA
   c) rRNA – help connect everything
   d) mRNA – message from DNA
3) Process
   a) ribosomes attach to mRNA
   b) starts at AUG, ribosomes indicate codon to tRNA
   c) tRNA anticodon bonds to codon to place amino acid in proper sequence
   d) enzyme in ribosome bonds amino acid with petide bond
   e) ribosome moves along mRNA so next amino acid can be attached
   f) when reaches stop codon protein released, ribosomes come off and mRNA breaks down

**Summary of DNA Role**



# Appendix F

Research Protocol Documents

Research Protocol Documents are on file in The Graduate College of Western Michigan University.

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