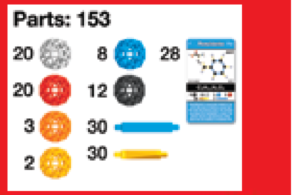
Zometool Project Series: the world's most powerful (and fun!) modeling system. Kids, educators, and Nobel-prize winning scientists all love Zometool:

- it's unique, brilliant, beautiful
- all kits are compatible—more parts, more power!
- guaranteed for life!

"The mind, once stretched by a new idea, never regains its original dimensions." *–Oliver Wendell Holmes*

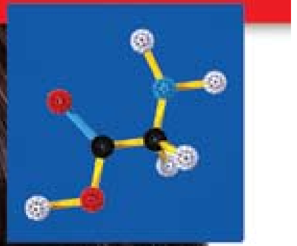
Bio Chemistry

Includes detailed instructions by Dr. Steve Yoshinaga



Discover the biological molecules involved in the central dogma of molecular biology: DNA to RNA to Protein. Learn how our genes, made of DNA, encode proteins. These processes are central to life.

- ***Unlock the molecular structures of DNA, RNA and proteins***
- ***Discover essential life processes***
- ***Learn about the magical building blocks of creation***
- ***See these molecules come to life!***



28 biochemistry cards included

MADE IN USA
from kid-safe materials

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WARNING: Choking Hazard
SMALL PARTS. NOT for children under 3 years.

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START HERE!

Biochemistry Kit 1: Numbers in Life

Biochemistry Kit 1 tells a story of numbers in life. The numbers are 1, 2, 4, and 20. These numbers relate to you, your genes, and all the molecules in DNA, RNA, and proteins.

DNA, RNA, and Proteins...Oh My!

You can build the molecules of life! To start using molecule cards and Zometool components right now, turn to page 5 (QUICK START!)

DNA
↓
RNA
↓
Protein

You'll focus on DNA (Deoxyribo-Nucleic Acid), RNA (Ribo-Nucleic Acid), and proteins. There are many important biological molecules, but all of them are created by proteins, and proteins are encoded by DNA and RNA. You will build the *monomers* of these incredible *polymers* (a monomer is a single molecule subunit, while a polymer is a number of monomers connected together). All of these amazing molecules work together to give us life. To better understand life, we study these molecules.

A polymer is a chain of the same or similar molecules. Life uses variations in polymer sequences to create tremendous diversity of form and function.

The Big Idea

The "big idea" of molecular biology* states that the main function of genes, which are made of DNA, is to encode proteins. The DNA code isn't directly translated into proteins. DNA must first be transcribed into a closely related molecule called RNA. DNA is the code, RNA is the message to make the code, and protein is the final product of the code. Thus, DNA goes to RNA goes to protein.

**i.e., the central dogma of molecular biology*

Life is simple as 1, 2, 4, 20!

We can look at life as a connection between numbers.

- 1 is for you! You are a unique life-form!
- 2 is for your 2 parents and the 2 sets of genes they gave you.
- 4 is for the 4 code molecules in DNA (G, C, A, T) or RNA (G, C, A, U). DNA and RNA code for proteins.
- 20 is for 20 of nature's ultimate building blocks, amino acids. These 20 building blocks, in different combinations, make all the proteins in us.

1 **You**
↓
2 **Parent's genes**
↓
4 **DNA code molecules**
↓
20 **Amino acids**

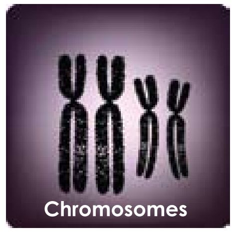
I am one!

The number 1 represents you. You are unique and the only 1 of your kind. Celebrate your uniqueness! Unless you are an identical twin, there is no one else on earth with the same genetic background as you. The genes in your cells make you special: they contain the plans that make you different from every other person on this planet.

The structures of life are amazing, but simple. How these structures work together to make a living being is almost magical. There are still great mysteries to be solved. You could be the 1 to solve them!

Thanks Mom and Dad!

The number 2 represents your 2 parents. Two also represents the 2 sets of genes, or blueprints, you inherited from your 2 parents. Your genes are the first and the most important things you got from them.



Chromosomes

Your parents inherited their genes from their parents, and so on, back through countless generations. Your genes have all the instructions to make you. Each of your cells has these genes on structures called chromosomes.

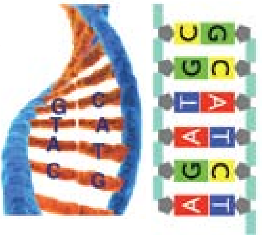
DNA

Your genes are written in a code contained in a double helix of molecules called DNA. DNA is the code of life!

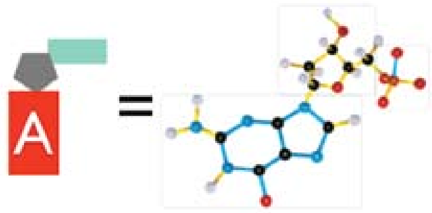
Life's simple code

Life's plans are written in a simple code using 4 molecules of DNA, called bases. These 4 base molecules are conveniently represented by the base letters G, C, A, and T, and they can be envisioned as the rungs of the twisted ladder that is a DNA double helix. There are millions of coding bases connected together in a single polymer. We have billions of these bases in each of our cells.

DNA is a helix of two strands: *Bases interact between the strands and hold them together. G bonds with C, and A bonds with T.*



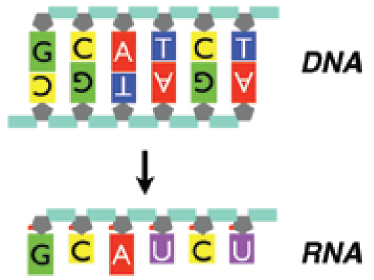
Making Life: One atom at a time
You can see life at the molecular level! Use your Life Molecule cards and your atoms and bonds to make the individual molecules important for life.



The number 4 also represents the number of coding base molecules in RNA. RNA is patterned after your DNA, and it is made when the cell needs to express the protein encoded by a gene. This first step in gene expression is called transcription. Once the DNA is transcribed into RNA, it acts as a message to the cell to make the protein. The RNA message is very similar to the DNA it is made from, but instead of the base T, RNA uses a similar base molecule, represented by the letter U.

While DNA is made from two strings of G, C, A, and T's and forms a twisted ladder called a double helix, RNA is usually a single strand made of G, C, A, and U's.

Transcription

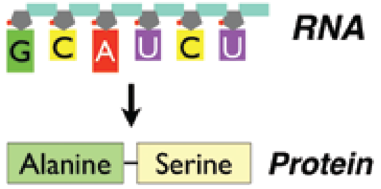


You can learn more about how DNA and amino acids work at our websites: www.magdna.com or www.zometool.com
Look for the education links.

Ultimate Building Blocks

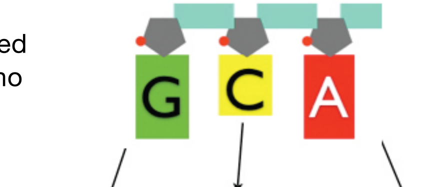
So what do DNA and RNA code for? That's where the number 20 comes in. DNA and RNA code for 20 of life's ultimate building blocks, called amino acids. The 20 different amino acids provide 20 diverse building blocks to make proteins. A gene, made of DNA, is chiefly a code to make the proteins that are critical in almost every function of our cells. After the DNA is transcribed into RNA, cellular machines translate the RNA message into strings, or polymers, of amino acids.

Translation



The process of turning the RNA code into a protein is called *translation,* because while the languages of DNA and RNA are very similar, the language of RNA has to be translated into the very different language of amino acids.

Breaking the Genetic Code

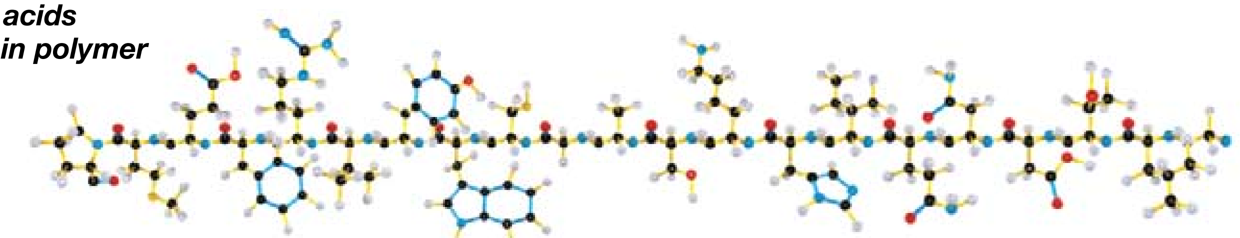


Second Base in Codon

First Base in Codon	U	C	A	G	*Third Base in Codon*
U	Phe	Ser	Tyr	Cys	U
	Phe	Ser	Tyr	Cys	C
	Leu	Ser	STOP	STOP	A
	Leu	Ser	STOP	Phe	G
C	Leu	Pro	His	Arg	U
	Leu	Pro	His	Arg	C
	Leu	Pro	Gln	Arg	A
	Leu	Pro	Gln	Arg	G
A	Ile	Thr	Asn	Ser	U
	Ile	Thr	Asn	Ser	C
	Ile	Thr	Lys	Arg	A
	Met	Thr	Lys	Arg	G
G	Val	Ala	Asp	Gly	U
	Val	Ala	Asp	Gly	C
	Val	Ala	Glu	Gly	A
	Val	Ala	Glu	Gly	G

In this universal genetic code, the strings of the RNA encode strings of amino acids: a sequence of three RNA bases encodes a particular amino acid. The next three bases in the string encode the next amino acid, and so on. A three base code is called a "codon", and each amino acid has at least one specific codon. Since there are 4 possible bases at three different positions, there are 4 X 4 X 4 = 64 possible codons, which are more than enough for the 20 amino acids. There are also specific codons to signal the beginning and the end of an amino acid chain.

Proteins are extremely varied in size and function, and this variety is a function of these amazing building blocks. Amino acids are large or small, positively-charged, negatively-charged or uncharged, bent or straight, or even rings and charged rings. This incredible diversity of building blocks allows nature to come up with vast diversity in proteins, and therefore, in life. Think of all of the amazing things that life can do -- those abilities are the functions of proteins in cells.



20 amino acids in a protein polymer

All Life is Connected

These life molecules are shared among all species on earth. All life is controlled by the same life code and built with the same building blocks. In fact, we share a significant number of genes with all life, and there are many species with genes that share over 90% identity with human genes. Studying biology is a wonderful way to appreciate our connection with life.

The Life Molecule Cards

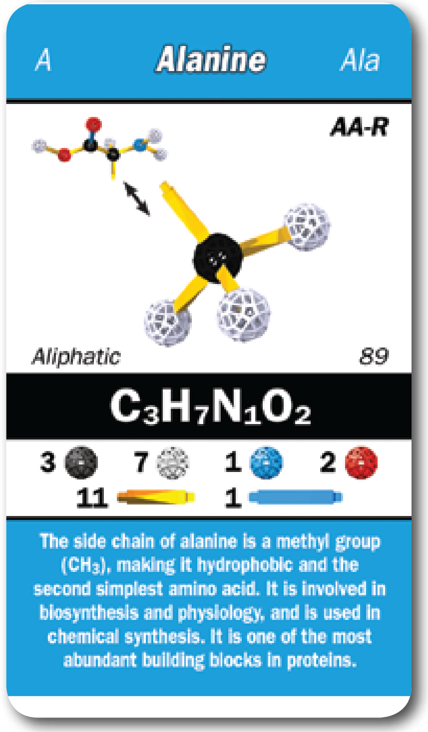
The way to build these life molecules and learn about them is through the Life Molecule Cards. There are 28 Life Molecule Cards included in each kit. They are: 20 amino acid cards, 5 base cards (G, C, A, T, and U), and cards for the ribose sugar, deoxyribose sugar, and phosphate molecules.

Life is 3-D

The name and abbreviation(s) for the molecule are at the top of the card. An atom by atom picture of the molecule is in the middle of the card. You will build what you see in the picture, but remember that the picture is 2-D, and real life is 3-D! Use what you know about molecular architecture (the *Molecular Modeling with Zometool* handout will help) to build a 3-D molecule that looks like the molecule on the card.

Amino Acid Cards

On all the amino acid cards, except for glycine, the molecule is broken in two. This is indicated by "AA-R" on the upper right side of the card. Amino acids are molecules that have a unique part, called the "R" group, and a part shared in all amino acids, called the core amino acid. The "R" group is in the center and the core amino acid is in the left background of the card. The complete amino acid would be connected at the empty bonds in the picture. Glycine is the simplest amino acid, with a single hydrogen (H) as the "R" group, and therefore the entire molecule is shown.



A **Alanine** Ala

AA-R

Aliphatic 89

$C_3H_7N_1O_2$

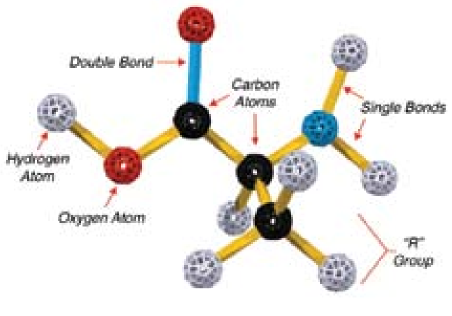
3 ● 7 ● 1 ● 2 ●

11 ▬ 1 ▬

The side chain of alanine is a methyl group (CH_3), making it hydrophobic and the second simplest amino acid. It is involved in biosynthesis and physiology, and is used in chemical synthesis. It is one of the most abundant building blocks in proteins.

QUICK START!

1. Study the molecule on the card.
2. Find the parts you need from the parts bar on the card and collect them.
3. Build the molecule with the parts, following the rules in the *Molecular Modeling with Zometool* handout.
4. Compare your model with the picture on the card.
5. Show the model to your friends.



Amino Acid: Alanine

The numbers 1, 2, 4, and 20 take us from you (1), to the plans your parents gave you (genes, 2), then to the coding molecules in those plans (DNA or RNA, 4), and finally to the building blocks (amino acids, 20) encoded by your plans.

Whether you want to ask better questions or learn better answers, Zometool is your ticket to discovery and fun. From numeracy to nano-technology, quasicrystals to quantum mechanics, the destination is always the same: better understanding of our amazing universe.

Our mission:

- make learning fun,
- create value,
- build a better world.

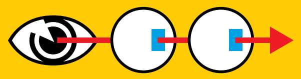
Discover more! Please **visit zometool.com** or call **888-966-3386** or **303-297-3387**.

Zometool Biochemistry Kit 1 Project -- thanks to Dr. Steve Yoshinaga, concept and copywriting; Dr. Brenda Yoshinaga, editing; Dr. Scott Vorthmann, vZome software used for renderings; Anni Wildung and Tara Brouwer, graphic design; Paul Hildebrandt, project management, etc. Please send questions, comments and suggestions to paulh@zometool.com. Based on the 31-zone system discovered by Steve Baer, Zomeworks Corp., USA.

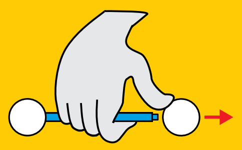
ZOMETOOL RULES!

① *If it works, it works perfectly.*

...and if it doesn't work, it doesn't work at all. Don't force Zometool components. You can bend a strut to fit it into a tight spot, but struts in finished models are always straight, never under tension. Hint: you can tell which strut fits between two balls in a model by lining up the balls and looking through the holes. The holes show you the shape of the strut that fits!



② *Don't break it apart; take it apart!*



Take models apart by grasping a strut with your fingers and pushing the ball straight off with your thumb. Twisting balls, pulling models apart or crushing them can cause parts to break!* To dissassemble a large model quickly, remove all the longest struts of one color first, and work your way down!

③ *Leave the place cleaner than you found it.*

It's always a good idea to clean up when you're done, so the next person can enjoy Zometool too. If we work together, we can make the world better for all.

We replace accidentally broken parts for free: visit **www.zometool.com/warranty for details.*