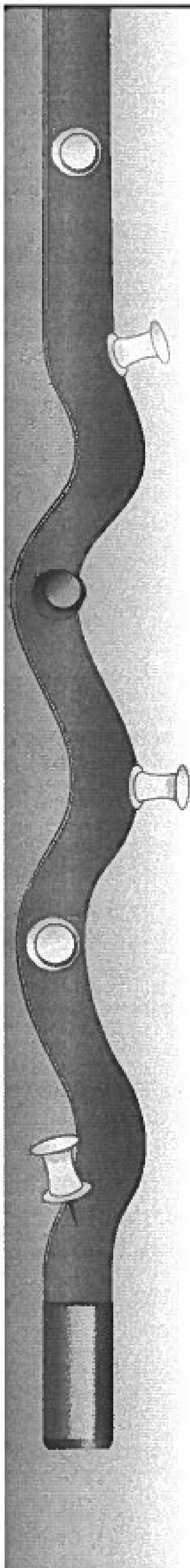
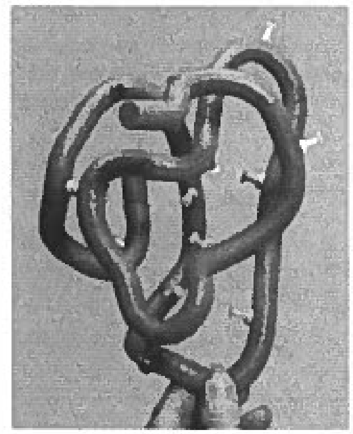


Protein Folding with 15 Tacks and a 4-Foot Mini Toober

Proteins are **more** than an important part of your diet. Proteins are complex molecular machines that are involved in nearly all of your cellular functions. Each protein has a specific shape **(structure)** that enables it to carry out its specific job **(function)**.

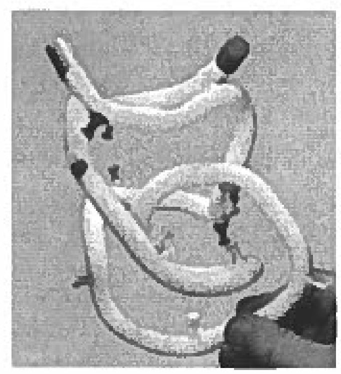


A **core idea** in life sciences is that ***there is a fundamental relationship between biological structure and the function it must perform.*** At the macro-level, Darwin recognized that the structure of a finch's beak was related to the food the finch ate. This fundamental structure-function relationship is also true at all levels below the macro level, including proteins and other structures at the molecular level.

In this activity you will explore the structure of proteins and the chemical interactions that drive each protein to fold into its specific structure.

Each protein is made of a specific sequence of **amino acids**. There are 20 amino acids involved in protein structure. Each amino acid consists of a unique combination of atoms and has a specific shape. The combination of atoms in each amino acid determines its properties which in turn cause the protein to fold into its correct structure. Amino acids are often called the **"building blocks"** of proteins and they can combine into hundreds of thousands of different sequences.

The protein models shown above and below were made following the 15 Tacks and a 4-Foot Mini-Toober activity



Based on the atoms in each amino acid, the amino acid could be ***hydrophobic, hydrophilic, positively charged, or negatively charged***.

Hydrophobic and Hydrophilic Properties

What do you think hydrophobic means? Separate the word 'hydrophobic' into its two parts — hydro and phobic. Hydro means water and phobia means fear or dislike, so hydrophobic sidechains (yellow tacks) don't like water. Hydrophobic sidechains are also referred to as non-polar sidechains.

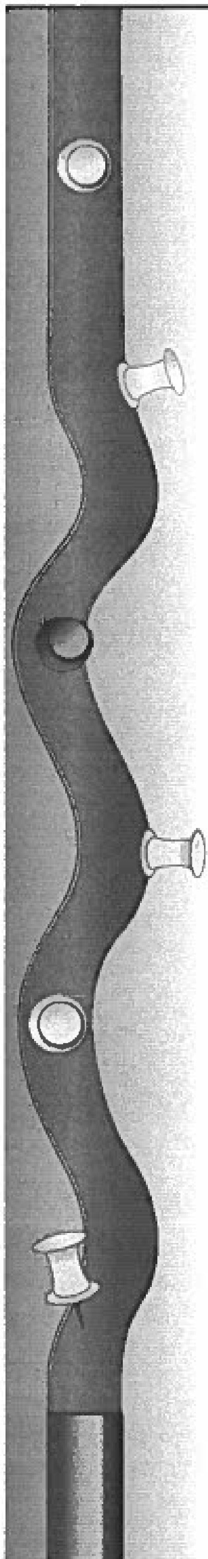
Now can you guess what hydrophilic means? Philic means likes or attracted to, so hydrophilic sidechains (white tacks) like water. Hydrophilic sidechains are also referred to as polar sidechains.

Acidic and Basic

Can you think of acids you have around your house? Lemon and fruit juices, vinegar and hydrogen peroxide, phosphoric acid (in dark sodas) are common household acids. Acids taste sour and are typically liquids.

Can you think of bases you have around your house? Tums, baking soda, drain cleaner and soap are common bases. Bases taste bitter and can be a liquid or solid.

What happens when you mix lemon juice or vinegar with baking soda? They neutralize each other.



Disulfide Bonds

A cysteine can interact with another cysteine to form a disulfide bond that helps stabilizes the folded protein.

Activity

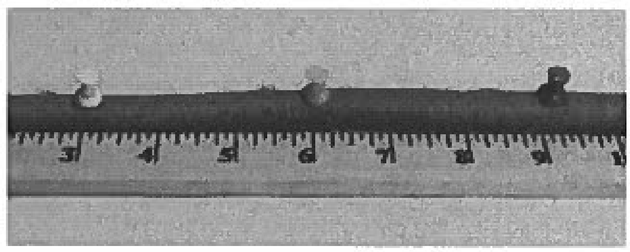
With 15 tacks and a mini-toober you can explore the principles of chemistry that drive protein folding. The color-coded tacks represent the properties of the amino acids.

Directions

1. Select 15 colored tacks according to the list below. The chart below indicates the properties of the colored sidechains.
    - 2 blue tacks
    - 2 red tacks
    - 6 yellow tacks
    - 3 white tacks
    - 2 green tacks

Blue Tacks represent basic amino acids (+ charge)
Red Tacks represent acidic amino acids (- charge)
Yellow Tacks represent hydrophobic (non-polar) amino acids
White Tacks represent hydrophilic (polar) amino acids
Green Tacks represent cysteine amino acids

2. Mix your colored tacks together and place them on the mini-toober about 3 inches apart.

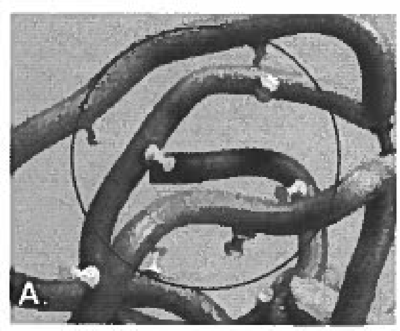


Note: As you push the tacks into the mini-toober, they may hit the wire in the middle and not go in all of the way. Reposition your tack so that it goes slightly above or below the wire.

Be careful not to push the tack through to the other side of the mini-toober where it can poke your finger. If you compress the foam near a tack it could also poke your finger. Also be careful not to tear the foam with the tack.

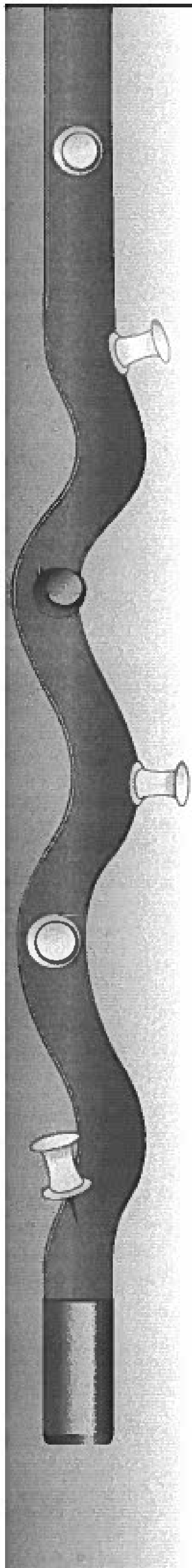
3. Now fold your protein, following the principles of chemistry that drive protein folding.

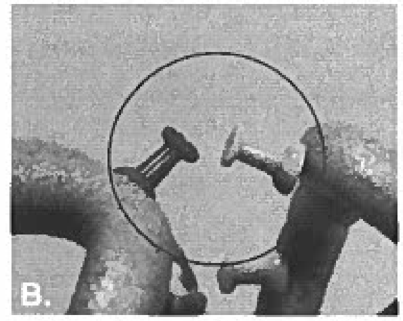
A stable protein simultaneously satisfies all of the principles of chemistry that drive protein folding, as described in A through D below and on the next page.



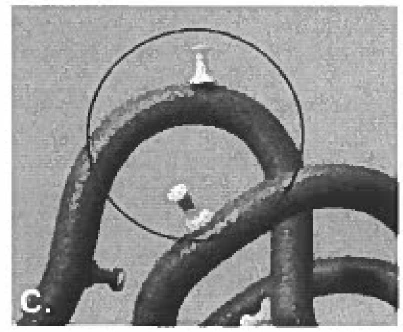
A. Hydrophobic (non polar) amino acids (yellow tacks) will be buried on the inside of the globular protein, where they are hidden from polar water molecules.

1050 North Market Street • Suite CC130A • Milwaukee, WI 53202
Phone: (414) 774-6562 Fax: (414) 774-3435
3dmoleculardesigns.com

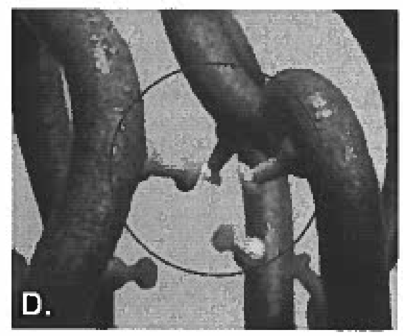




B. Charged amino acids (blue and red tacks) will be on the surface of the protein where they often neutralize each other to form an electric bond (salt bridges).



C. Hydrophilic (polar) amino acids (white tacks) will be on the surface of the protein where they can interact with water by forming hydrogen bonds.



D. Cysteine amino acids (green tacks) often interact with each other to form covalent disulfide bonds that stabilize protein structure.

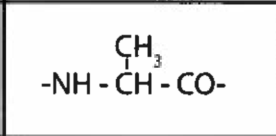
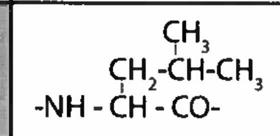
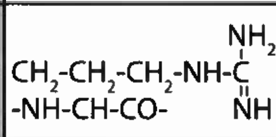
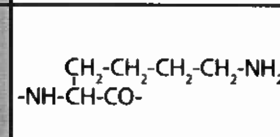
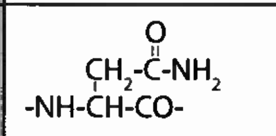
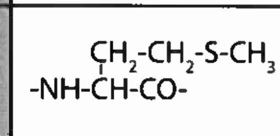
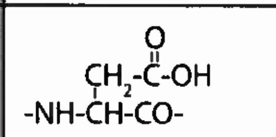
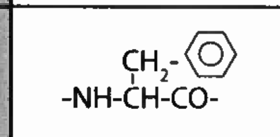
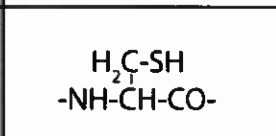
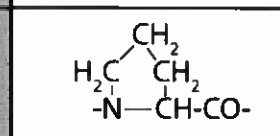
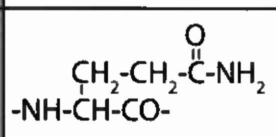
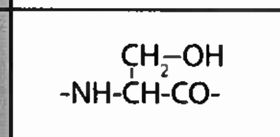
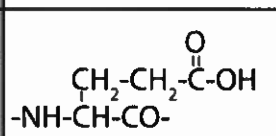
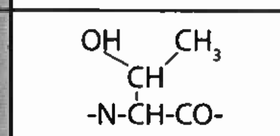
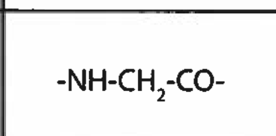
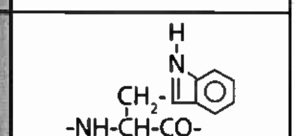
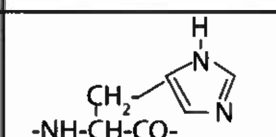
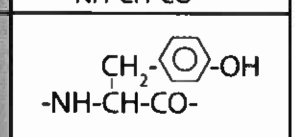
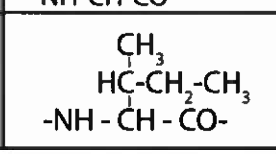
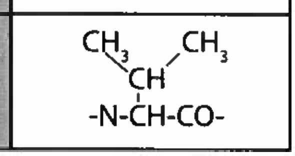
A chart of the sidechains and their properties is on page 4.

Discussion

Proteins perform critical functions in all of our cells. Without proteins life wouldn't exist. With your group or class, can you think of some of some specific proteins and describe what function they perform?

Proteins are involved in your metabolism, cell structure, immune system, DNA expression, protein folding, transport, movement, communication, and storing energy.

Amino Acid List

AA Name	AA	Code	Structure	AA Name	AA	Code	Structure
Alanine	Ala	A		Leucine	Leu	L	
Arginine	Arg	R		Lysine	Lys	K	
Asparagine	Asn	N		Methionine	Met	M	
Aspartic Acid	Asp	D		Phenylalanine	Phe	F	
Cysteine	Cys	C		Proline	Pro	P	
Glutamine	Gln	Q		Serine	Ser	S	
Glutamic Acid	Glu	E		Threonine	Thr	T	
Glycine	Gly	G		Tryptophan	Trp	W	
Histidine	His	H		Tyrosine	Tyr	Y	
Isoleucine	Ile	I		Valine	Val	V	

	Ala	Arg	Asn	Asp	Cys	Glu	Gln	Gly	His	Ile	Leu	Lys	Met	Phe	Pro	Ser	Thr	Trp	Tyr	Val
Acidic (negative)				D		E														
Basic (positive)		R							H*			K								
Charged		R		D		E			H*			K								
Neutral	A		N		C		Q	G	H*	I	L		M	F	P	S	T	W	Y	V
Hydrophobic (non-polar)	A							G		I	L			F	P			W	Y	V
Hydrophilic (polar)		R	N	D	C	E	Q		H			K	M			S	T			

*Under some conditions Histidine is neutral and in other conditions it has a positive charge.

Amino Acid Property Key: ● Negative Charge ● Positive Charge ○ Hydrophilic ○ Hydrophobic ● Cysteine