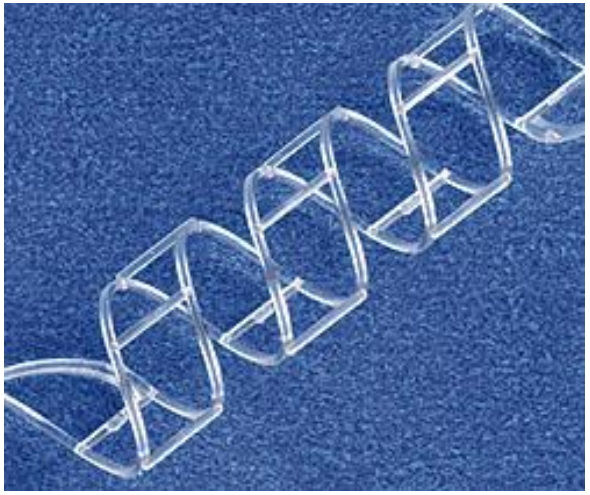
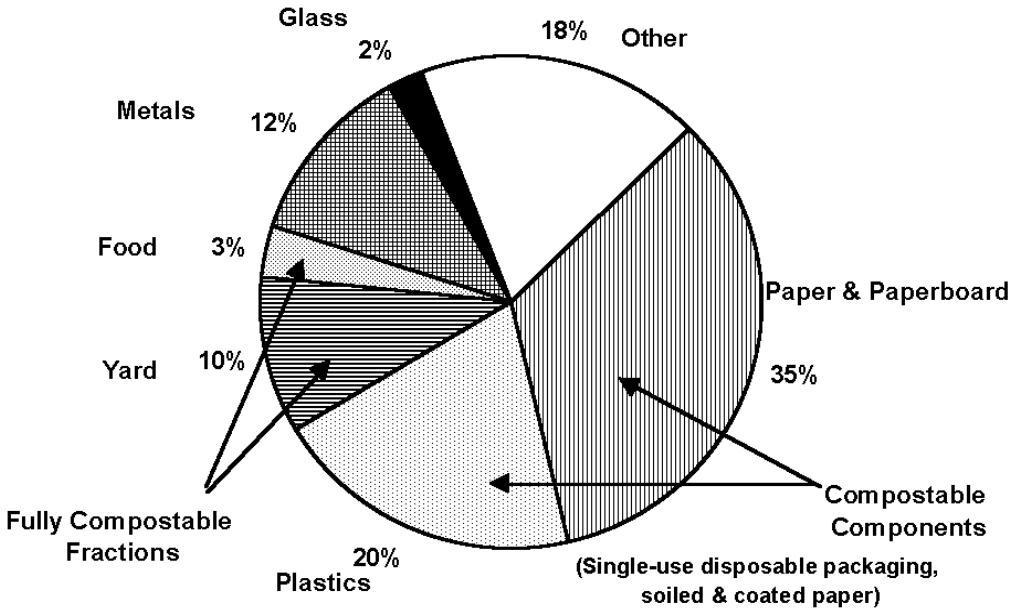
Mathematics and Science in Schools in Sub-Saharan Africa

Material Science



Biodegradable

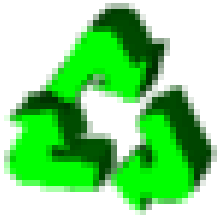
POLYMERS



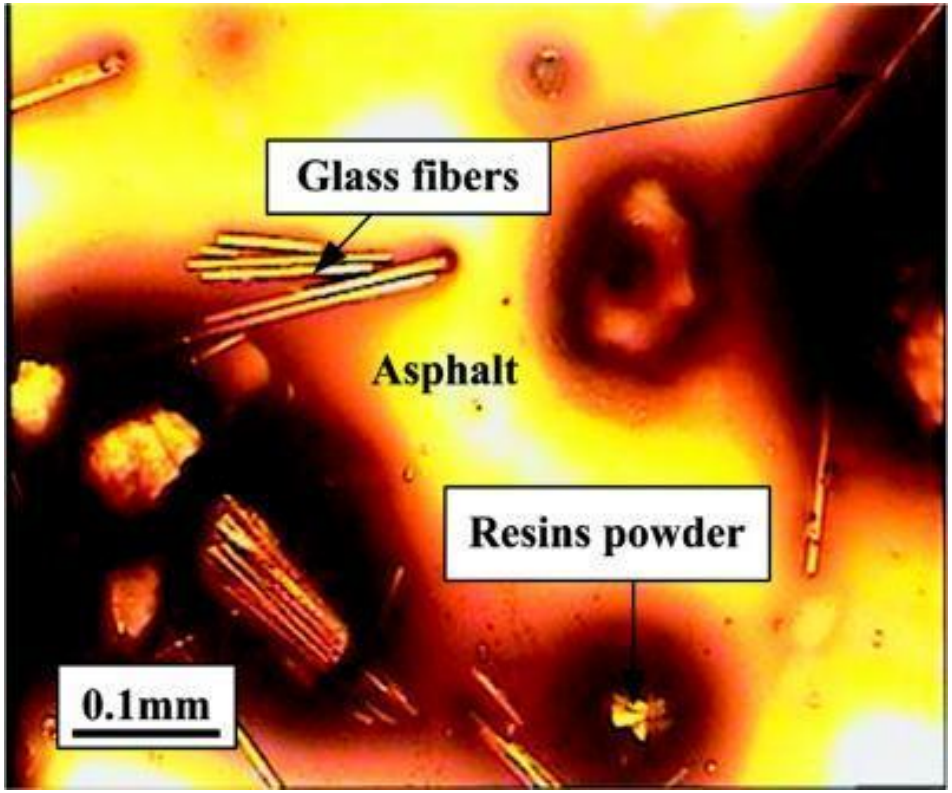
Each year, we produce millions of tons of garbage that are disposed of in landfills.


Reduce


REUSE
REUSE



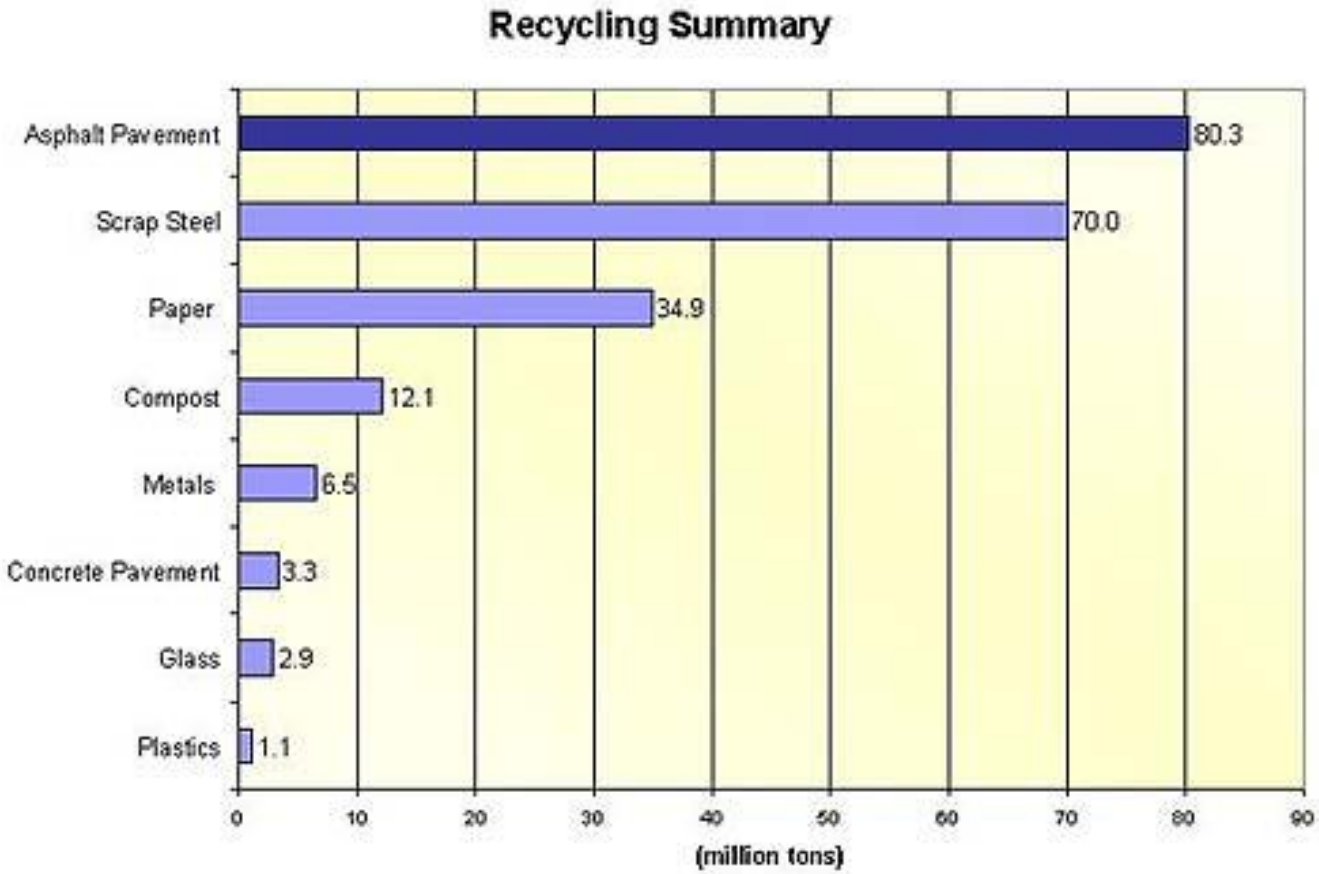
I.T.'s Superhighway Trash Yields A Super Highway Asphalt !



Discarded electronic hardware can be recycled into an additive that makes super-strong asphalt paving material for real highways.

The new material makes high-performance paving material asphalt that is cheaper, longer lasting, and more environmentally friendly than conventional asphalt.


PLASTIC


Recycling Summary
Asphalt Pavement
80.3
Scrap Steel
70.0
Paper
34.9
Compost
12.1
Metals
6.5
Concrete Pavement
3.3
Glass
2.9
Plastics
1.1
0
10
20
30
40
50
60
70
80
90
(million tons)

Plastic Recycle Codes

Polyethylene Terephthalate is inexpensive, lightweight and easy to recycle.

PET plastic is safe for single-use only!

High Density Polyethylene is a versatile plastic with many uses.

HDPE plastic is safe for multiple-use!

Polyvinyl Chloride is tough and weathers well.

PVC plastic contains chlorine, a dangerous toxin!

Low Density Polyethylene is a flexible plastic with many applications.

LDPE plastic is safe for multiple-use!

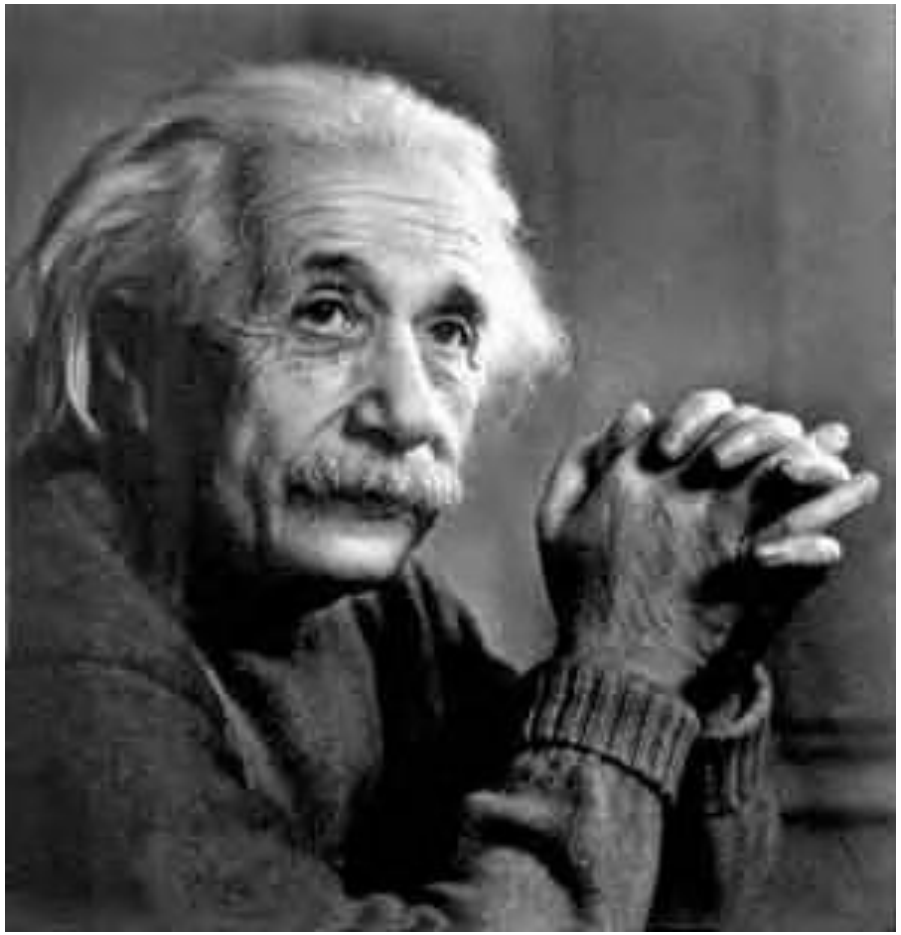
Polypropylene has a high melting point.

PP plastic is safe for multiple-use!

PS can be made into rigid or foam products.

Polystyrene plastic is safe for multiple-use!

Lab: Second Time Around



Lab: Second Time Around

Info Box

Solution	Density
52% Ethanol	*0.911*
38% Ethanol	*0.941*
24% Ethanol	*0.965*
6% $CaCl_2$	*1.0505*
32% $CaCl_2$	*1.306*
40% $CaCl_2$	*1.398*

Lab: Second Time Around

Data Chart

Sample #	Density
1	
2	
4	
5	
6	

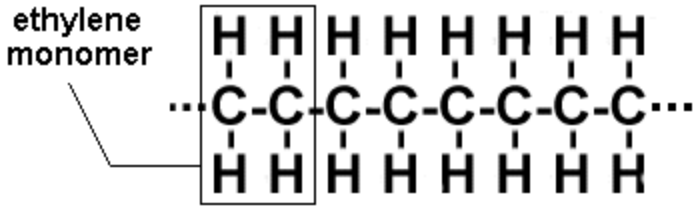
Lab: Second Time Around

Analysis

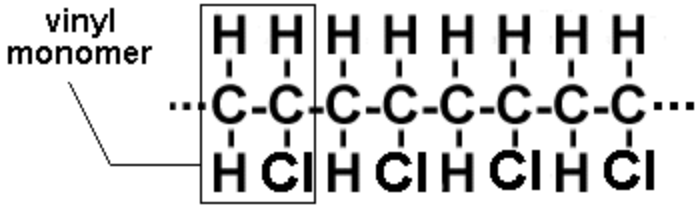
Sample	Identity

HDPE

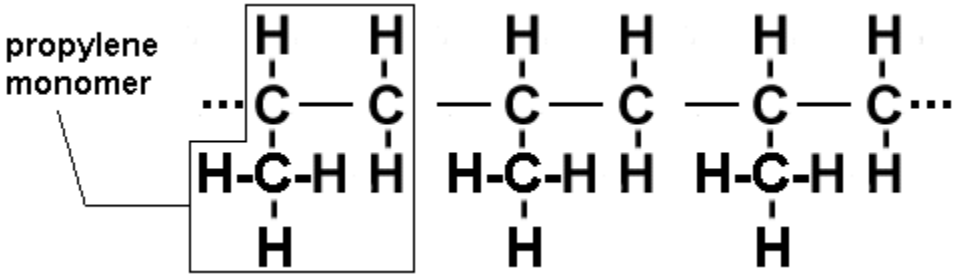
LDPE



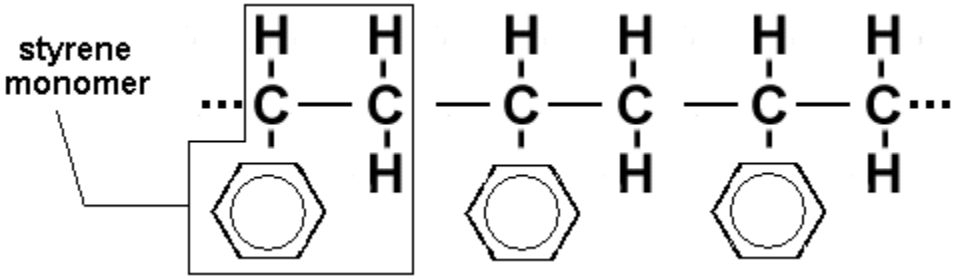
PVC



PP



PS

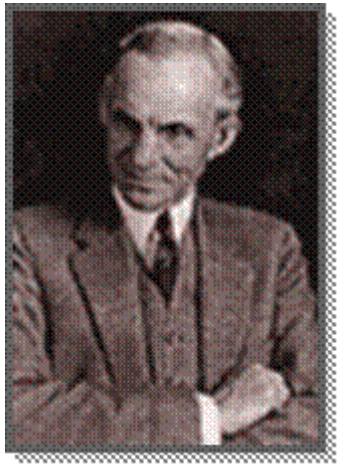


Biodegradables

Materials that are broken down by natural processes into non-toxic, reusable substances.

Almost all biodegradable materials are made of polymers.

1908



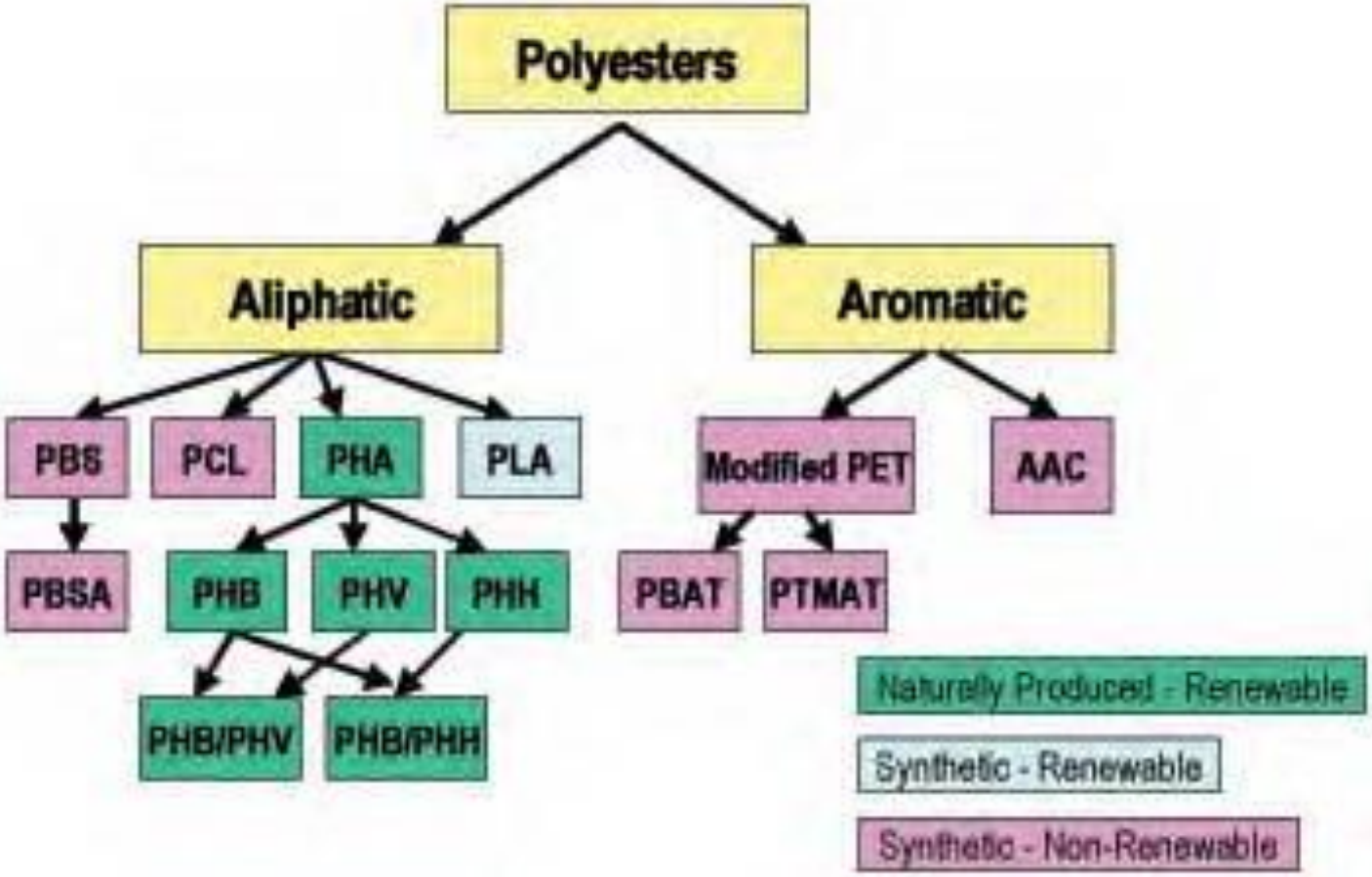
Jacques E. Brandenberger

Brandenberger succeeded in producing the first biodegradable plastic from the plant-derived structural polysaccharide cellulose.

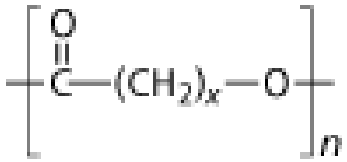
Cellophane

Ironically, at that time Cellophane's inherent biodegradability hampered its suitability for certain applications and it was quickly superseded by more conventional and durable plastics.

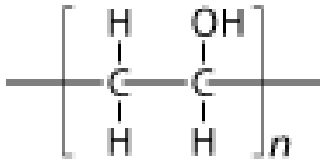
Biodegradable Polymers



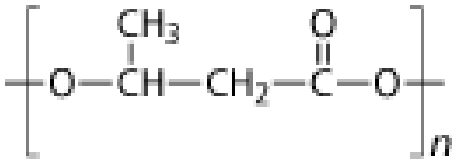
Biodegradable Polymers



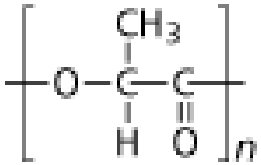
Polycaprolactone



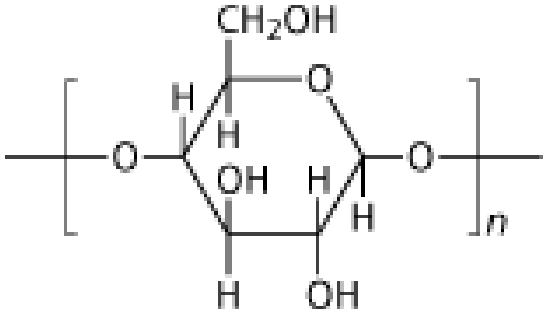
Polyvinyl alcohol



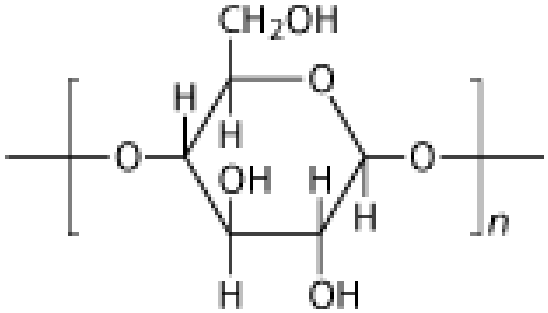
Polyhydroxybutyrate



Polylactic acid



Starch
α 1,4 linkage



Cellulose
β 1,4 linkage

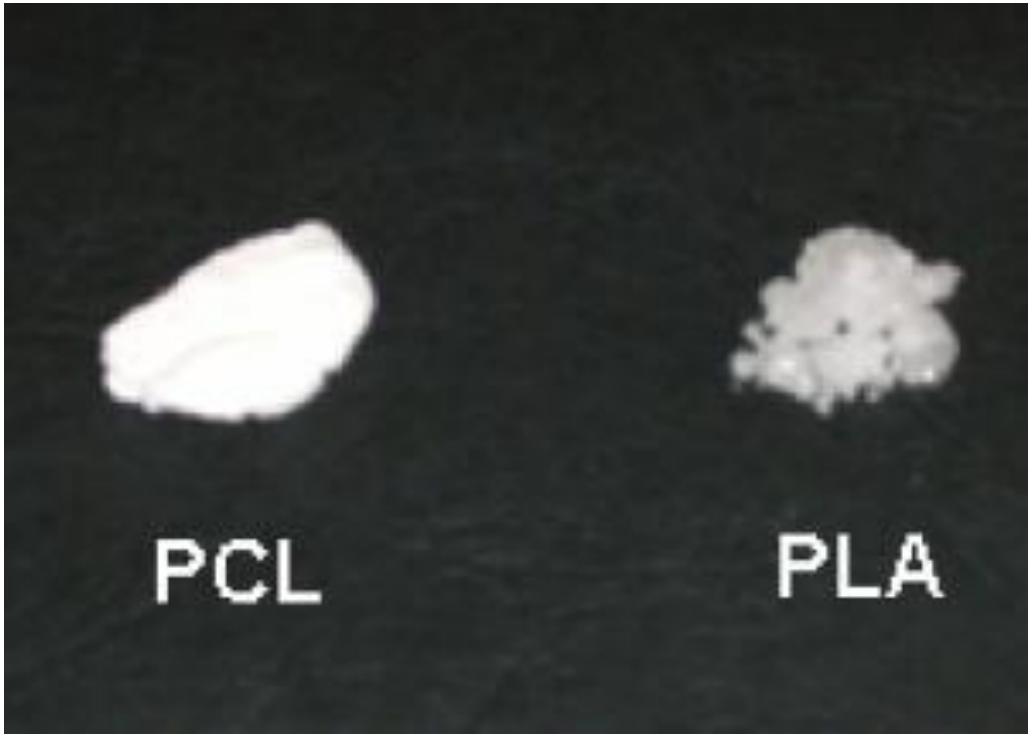
☺

Polymerized Lactic Acid (PLA)

NatureWorks™

Since only ~14% of plastic water bottles are recycled, a new plastic resin derived from corn byproducts (PLA) is now being used for plastic bottles.

Polymerized Lactic Acid (PLA)



PLA is a renewable natural resource that is commercially compost able in ~75 days and require 30% less energy & 50% less CO_2 to produce than conventional plastic.

Most polymers are not biodegradable!

Conventional polyethylene products can take longer than 100 years to degrade!

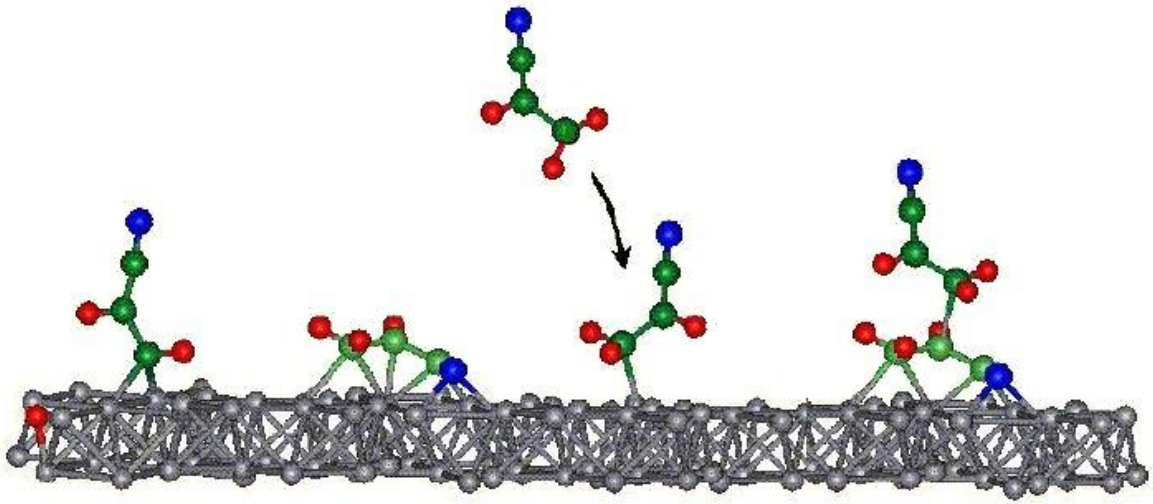
Biodegradable Time Clock

Product	Time to biodegrade
Cotton Rags	1-5 months
Paper	2-5 months
Rope	3-14 months
Orange peels	6 months
Wool socks	1 to 5 years
Cigarette filters	1 to 12 years
Plastic coated paper milk cartons	5 years
Leather shoes	25 to 40 years
Nylon fabric	30 to 40 years
Plastic bags	10-20 years
Plastic holder rings (6-Pack)	450 years
Glass	1 million years
Plastic bottles	Never

Symphony Environmental has produced new additive technology to reduce the plastic to carbon dioxide and water in just a few weeks.

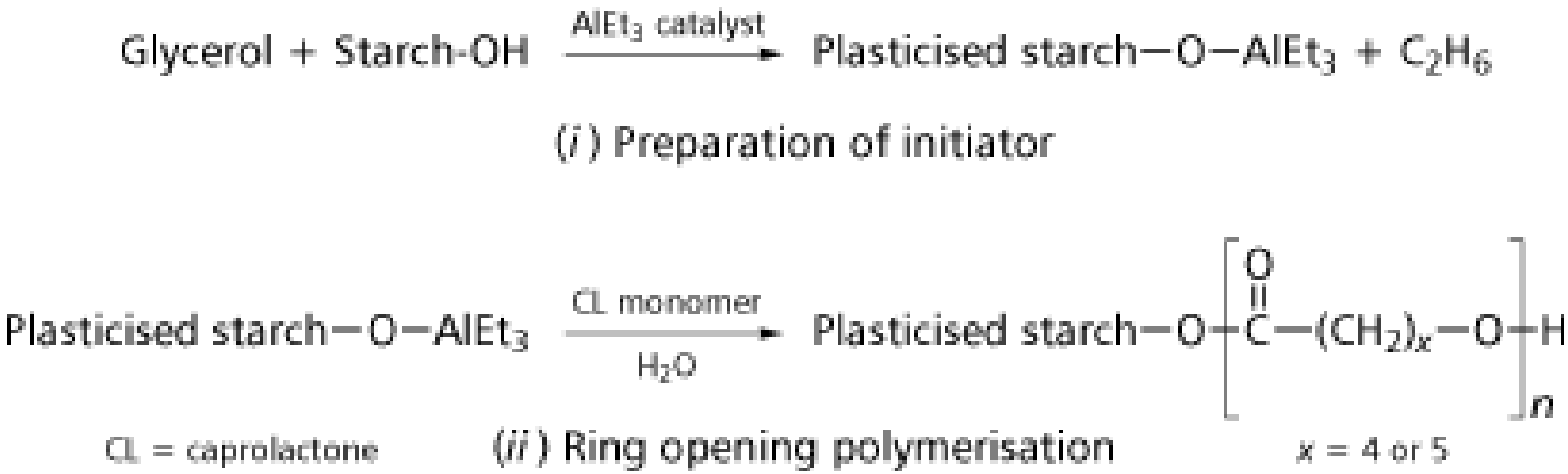
Improving Biodegradability

Grafting



Grafting allows a composite material made from two or more different components to function as a single material.

Grafting

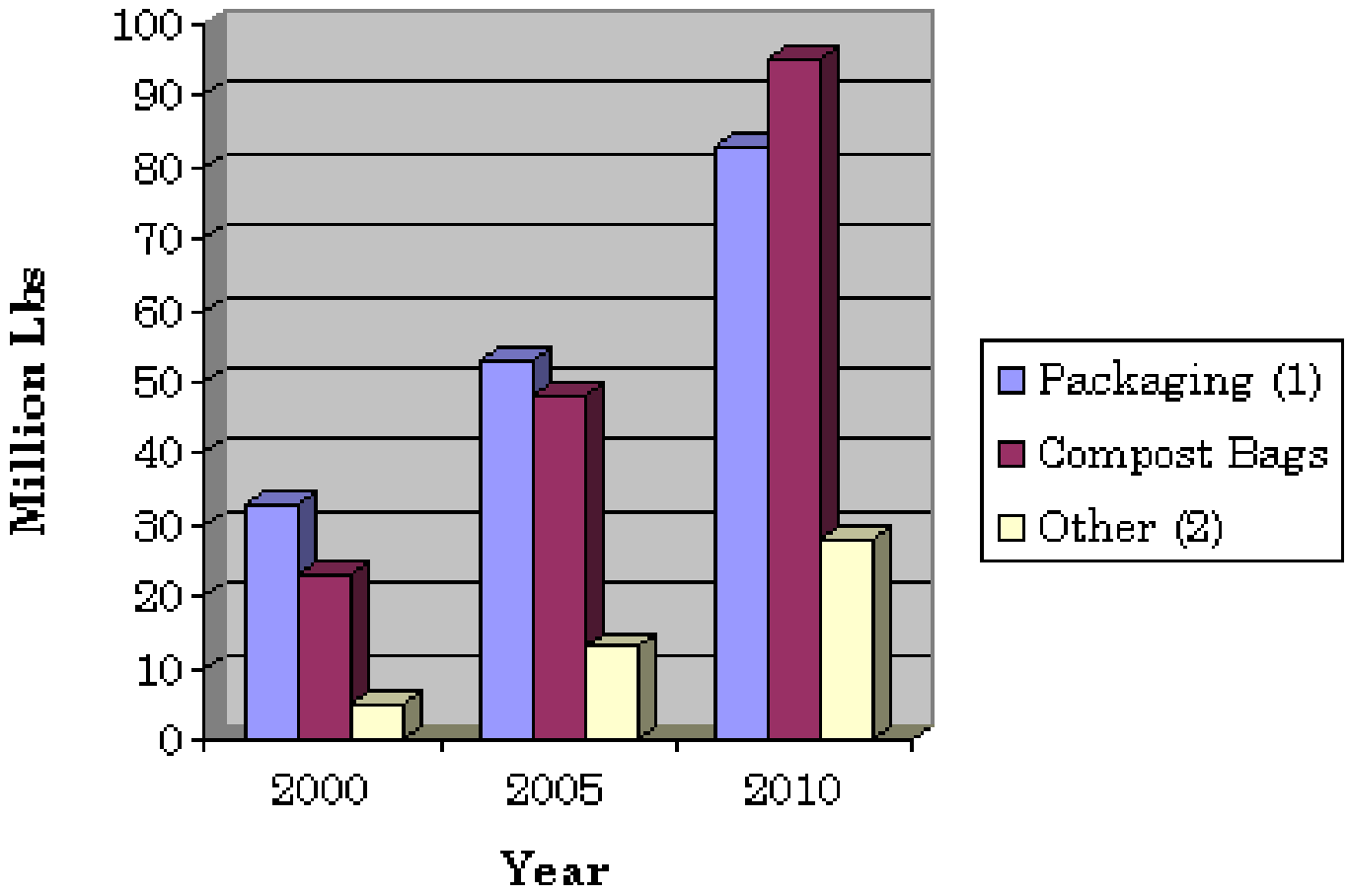


The goal is to combine the good physical properties of a synthetic polymer with a biodegradable partner.

Biodegradable Plastic Bags

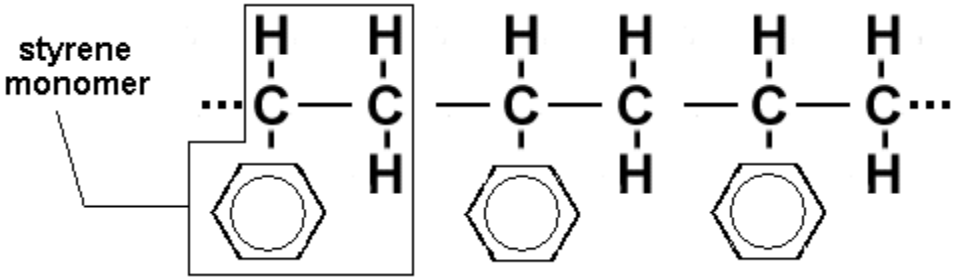
Microscope photograph X 2,000

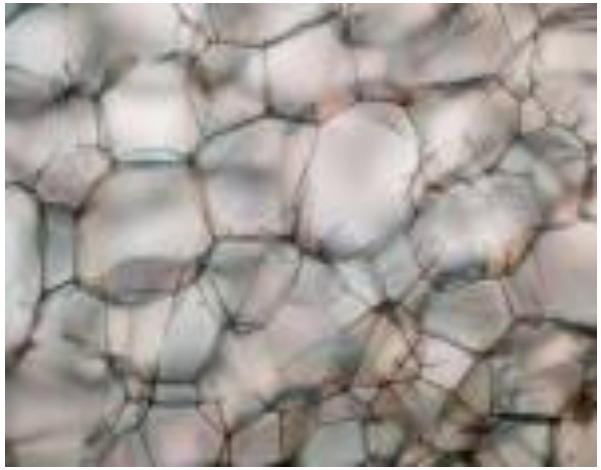
Three monthes after landfill

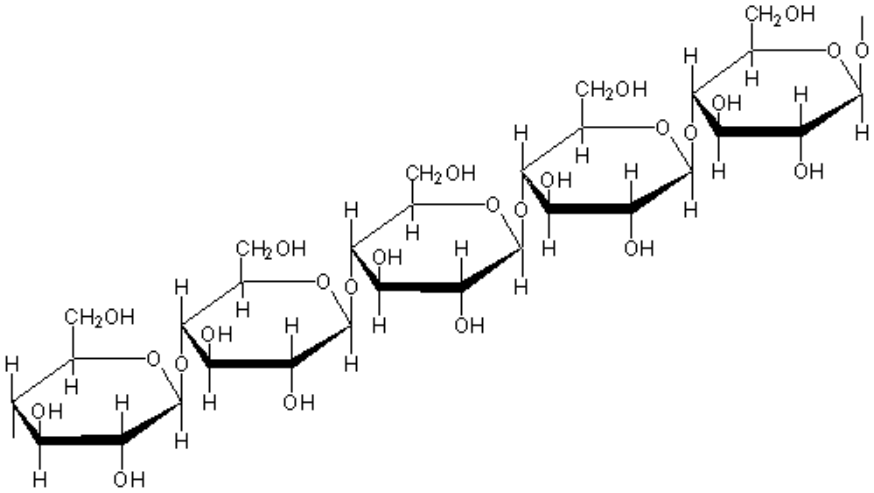


A biodegradable polymer does not generally sell simply because it is biodegradable, it must compete as a material on the basis of its own price/property characteristics, with biodegradability an added bonus.

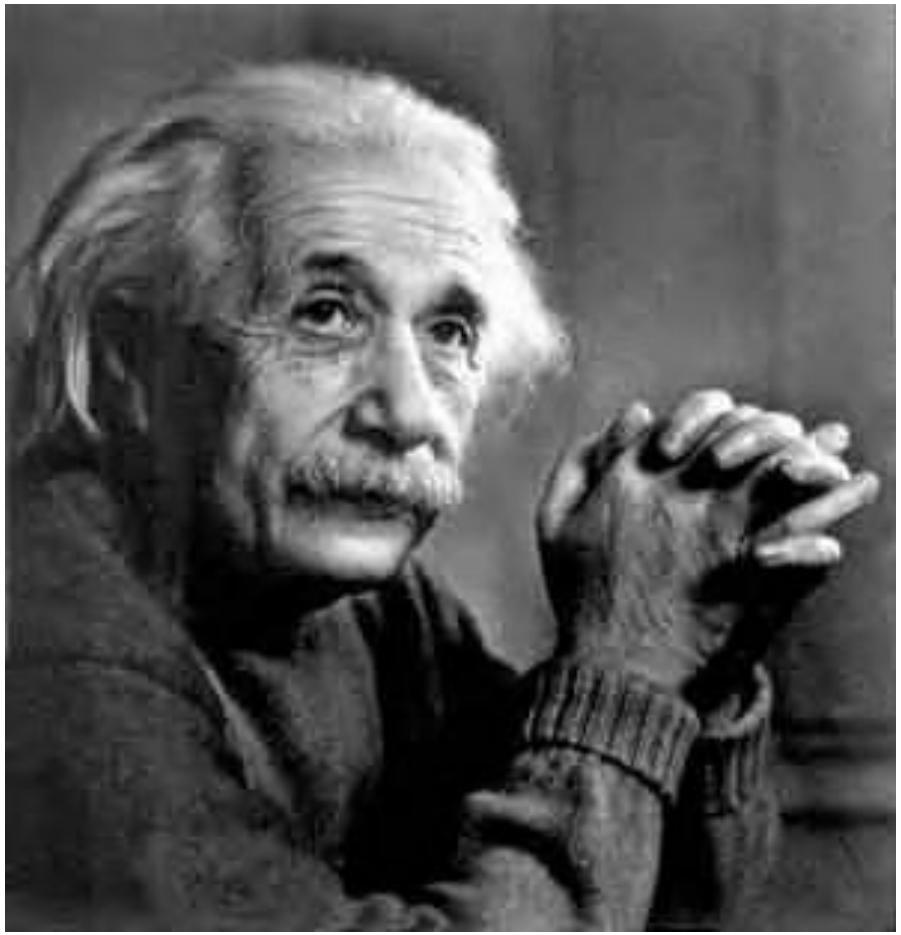
Biodegradable Packing







Lab: Biodegradable Packing

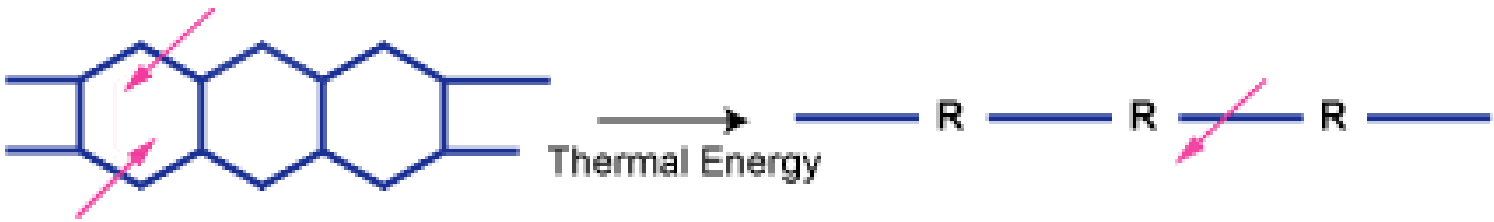


Lab: Biodegradable Packing

Data Chart

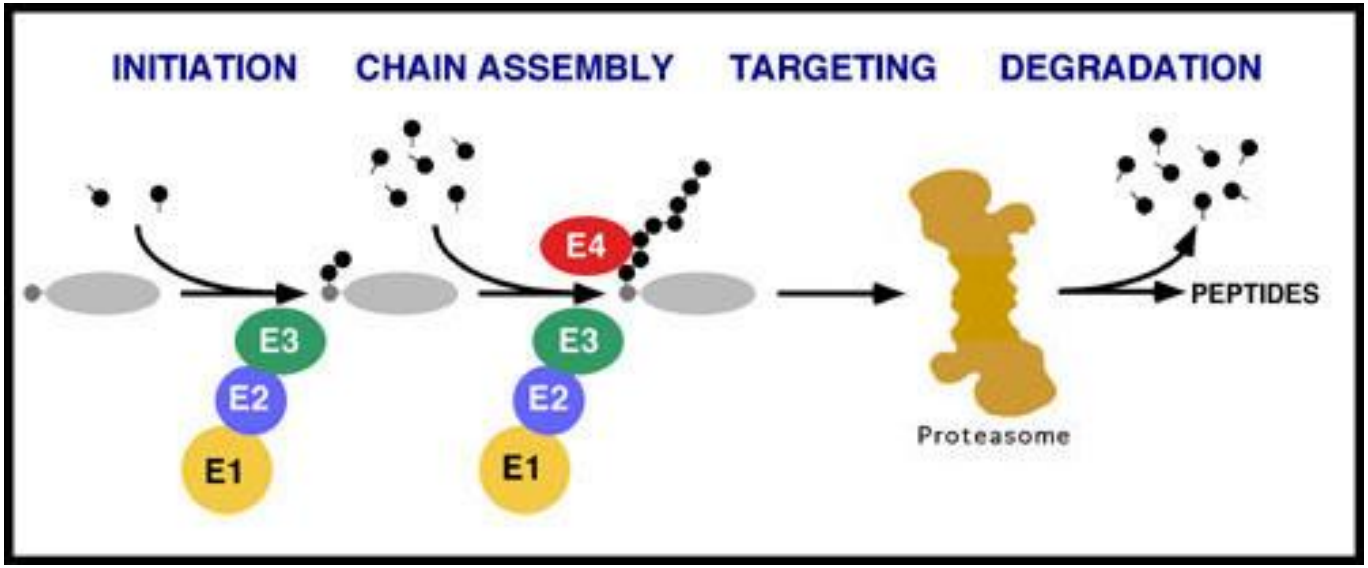
	Biodegradable	Non-Biodegradable
Stress	**Strain**	**Strain**

What is the Process of Biodegradability?



Polymer Degradation

Polymer Degradation



Any change of the polymer properties relative to the initial, desirable properties is called degradation.

Type I

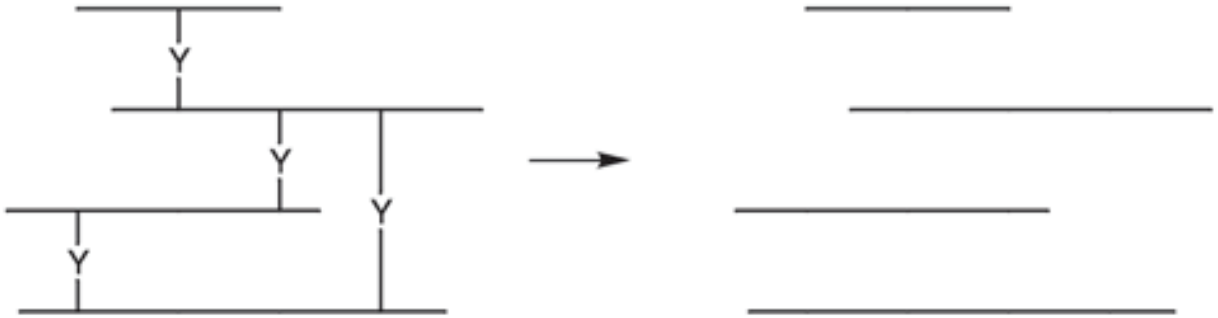
X represents the labile backbone bonds

Type II

A represents hydrophobic side groups

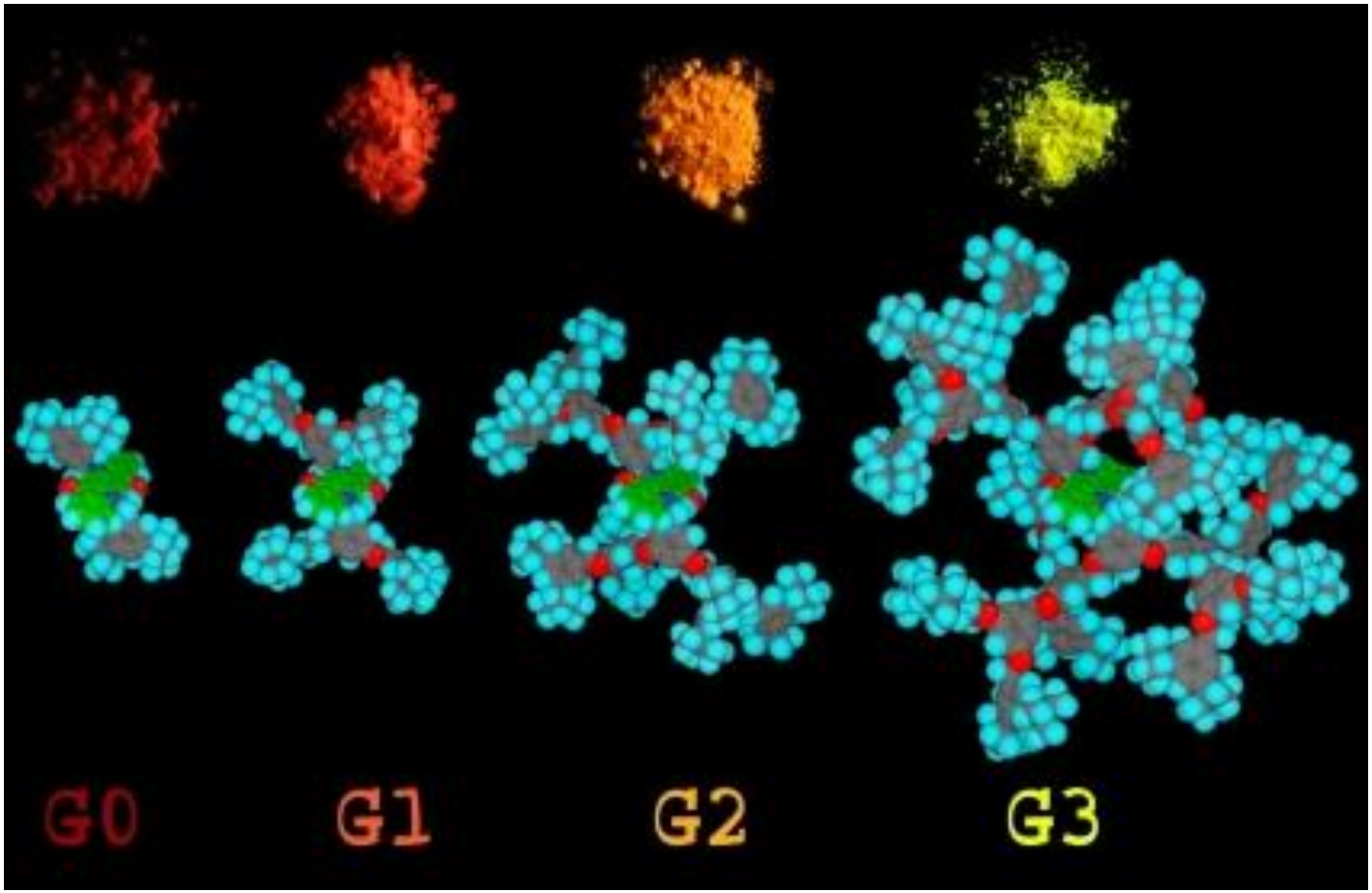
B represents hydrophilic side groups

Type III

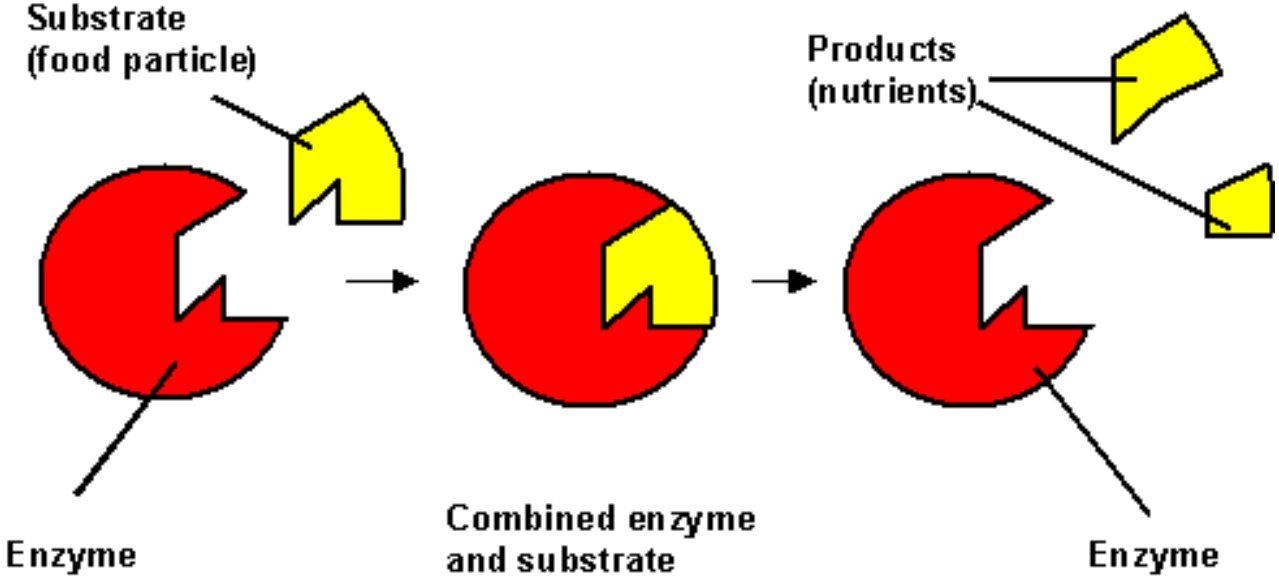


Y represents the crosslinks

Polymer Degradation Factors



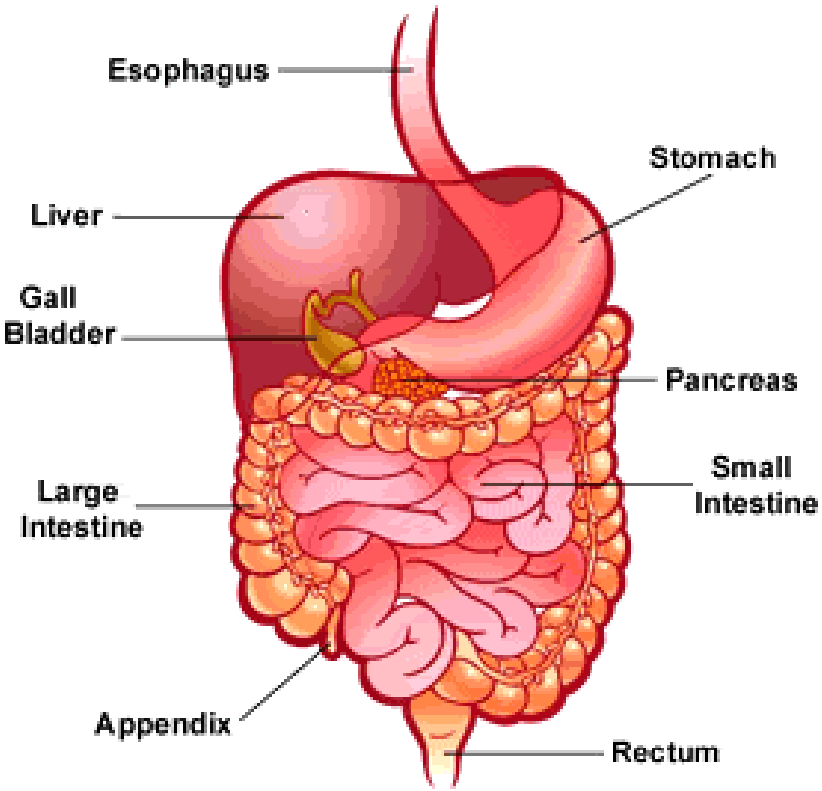
Enzymes

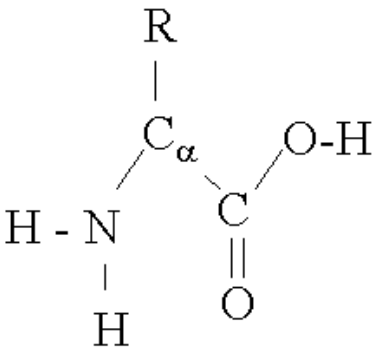


How enzymes break down food into nutrients

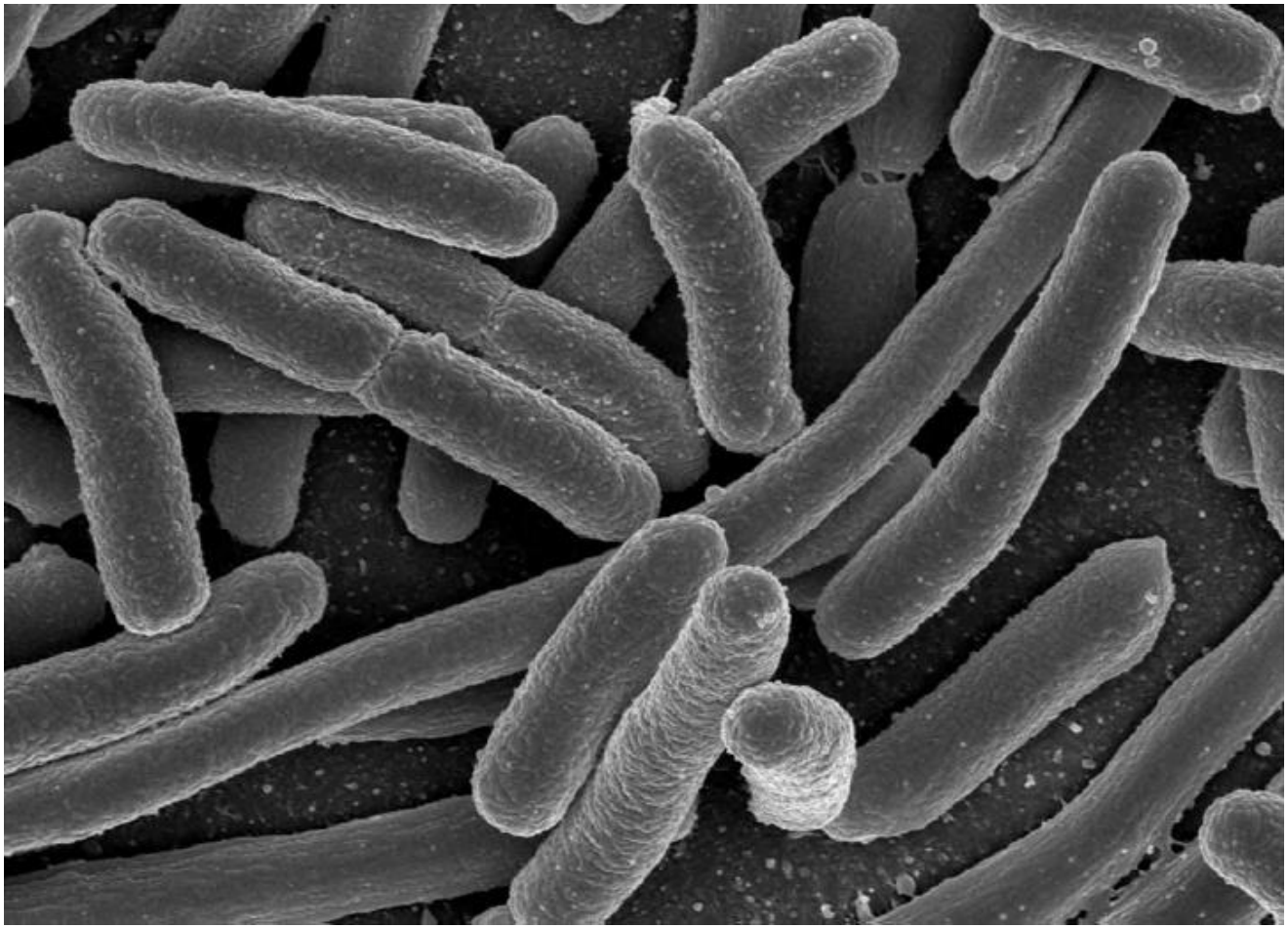
A protein functioning as a biochemical catalyst in a living organism.

Food


Esophagus
Stomach
Liver
Gall Bladder
Pancreas
Small Intestine
Large Intestine
Appendix
Rectum

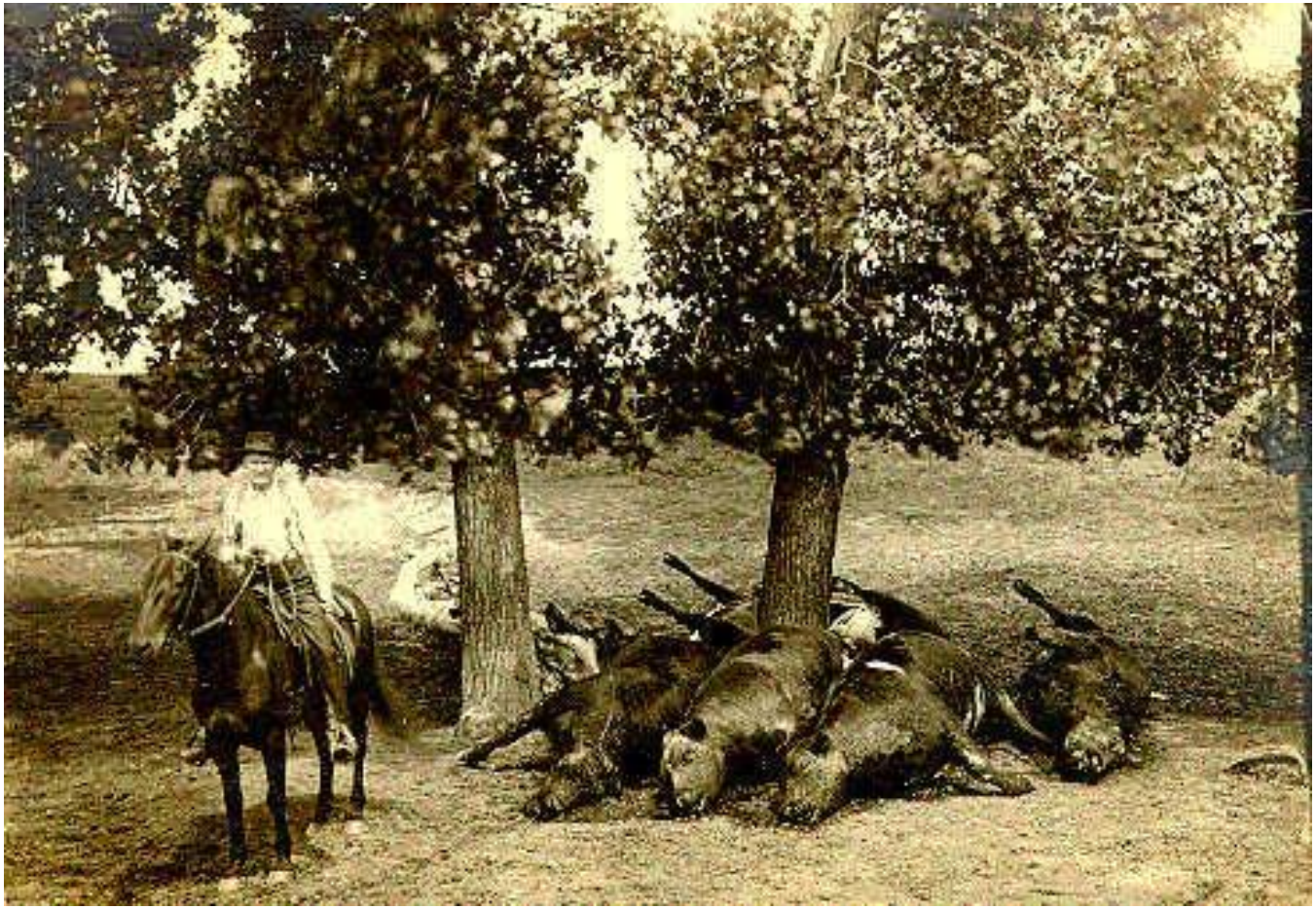

R
Cα
O-H
H - N
C
O
H

Microbial Action

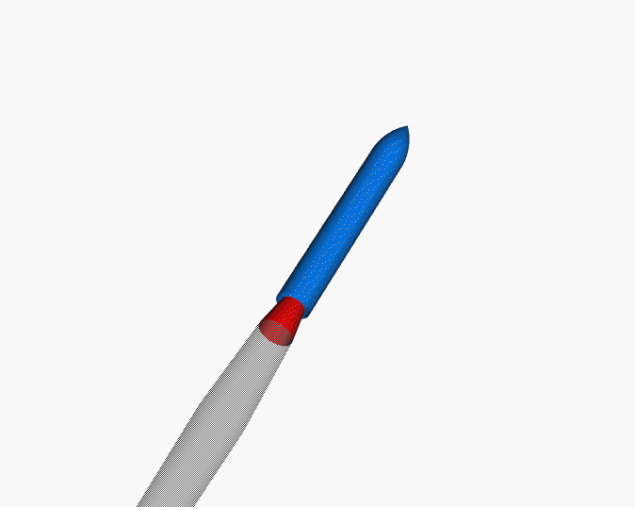


E. Coli

Microbial Action



Remains of dead organisms are decomposed by certain bacteria, fungi and algae.



Missile Propellants

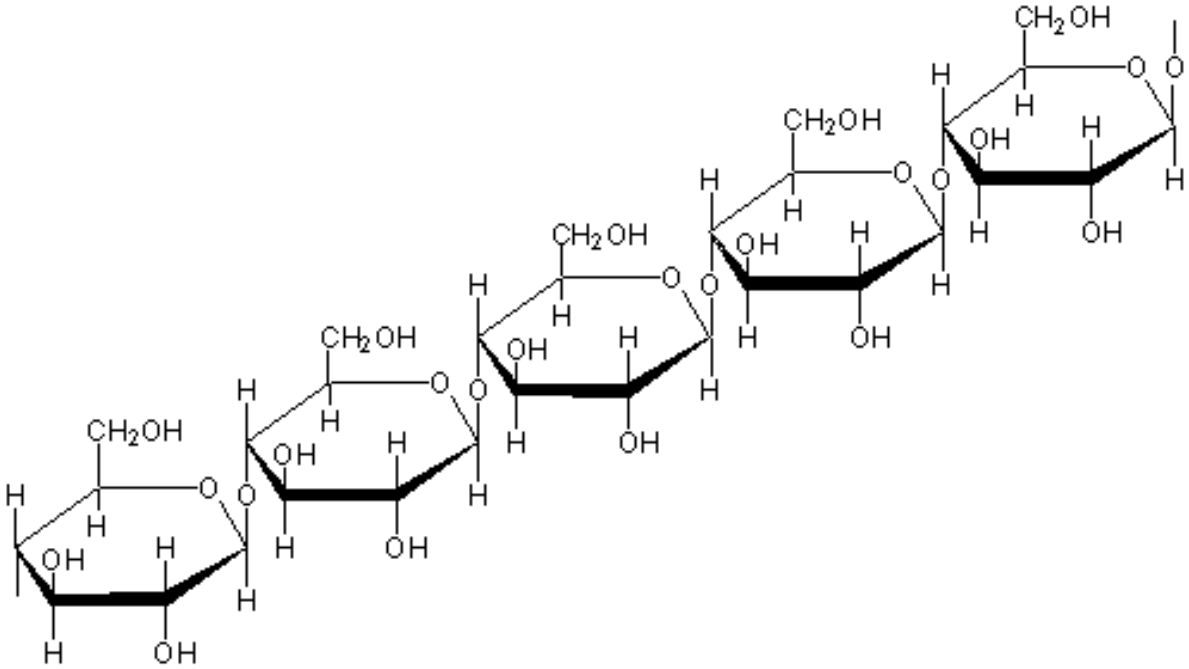
Sugar

Cholesterol-Lowering Drugs

SUMAR

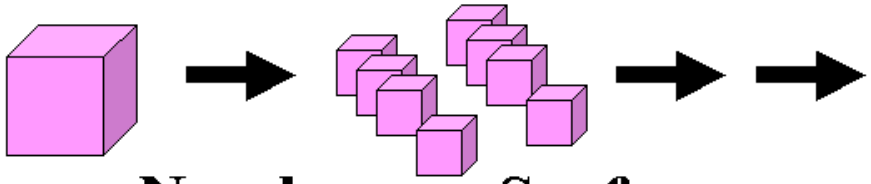
A specially made latex rubber that enables protein degradation by bacterial action that is controlled chemically.

Chemical Structure



Surface Area

Surface Area ∝ (1 / Size)

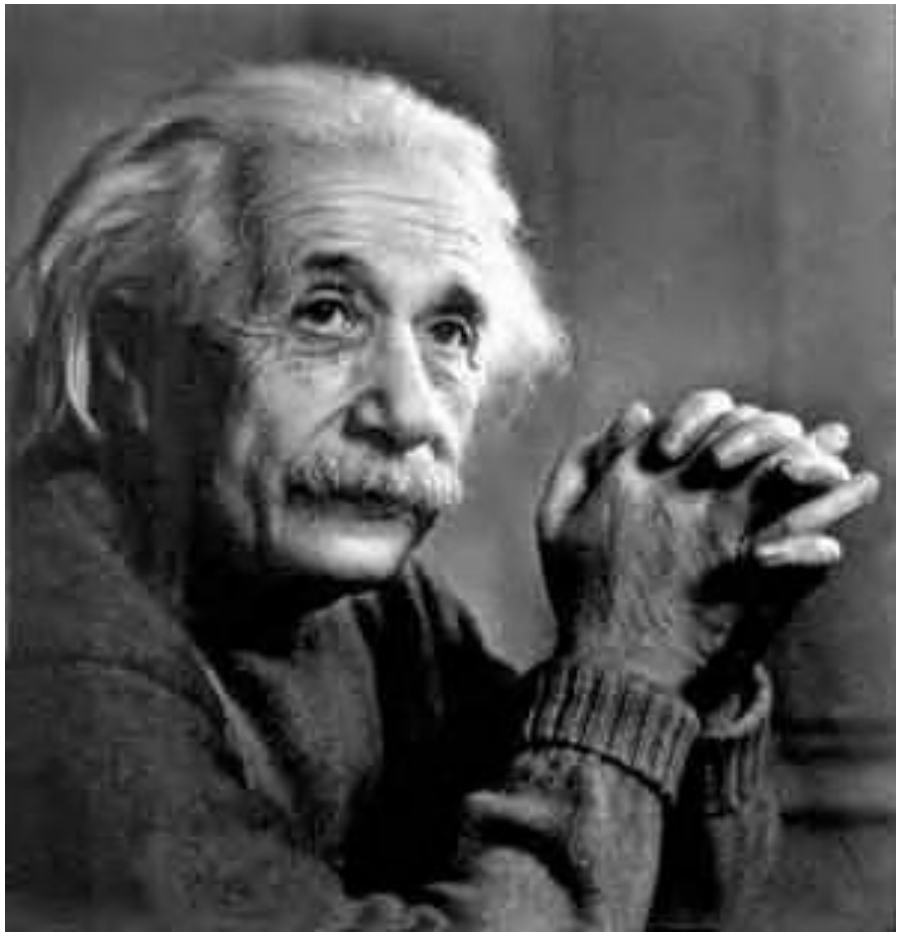


Edge (cm)	Number of cubes	Surface area (cm^2/g)
1	1	6
0.0001	10^{12}	60,000
(1 μm)	*(1 trillion)*	*(6 m^2/g)*

M. Hubbe

The amount of an object exposed to the environment.

Lab: Surface Area vs. Size & Shape

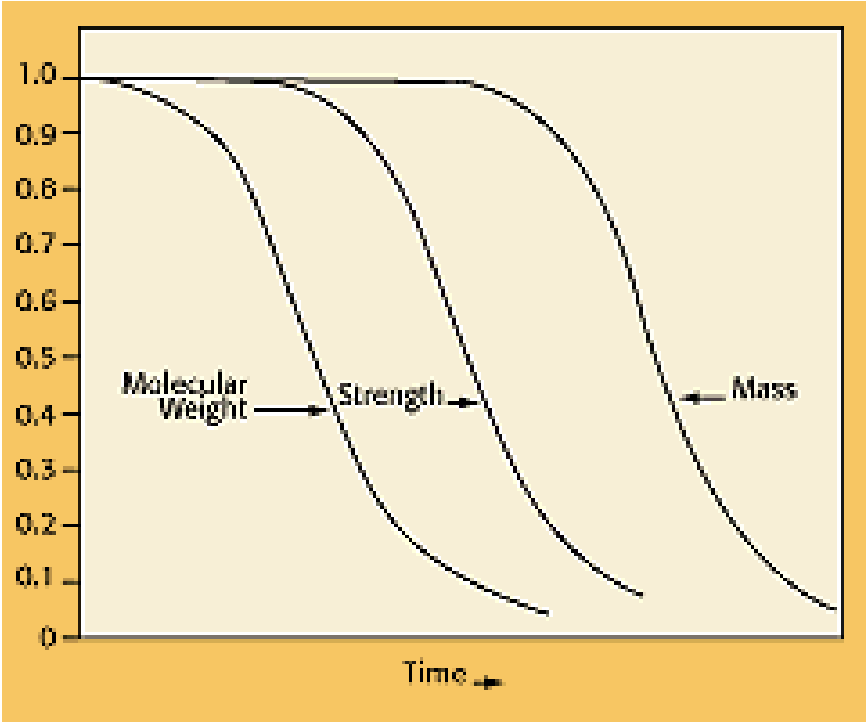


Interactive

Lab: Surface Area vs. Size & Shape

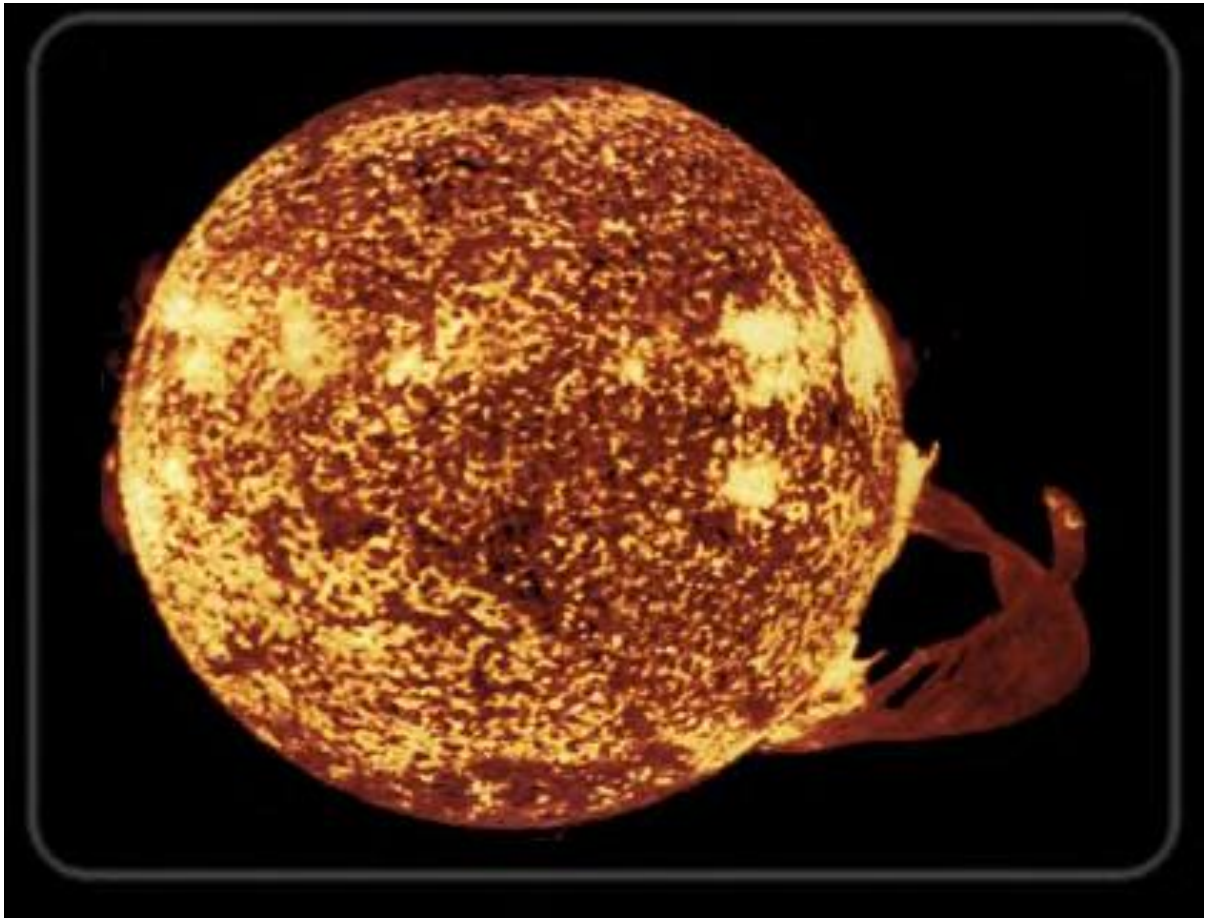
Geometric Shape(s)	Total Volume (cm^3)	Total Exposed Surface Area (cm^2)
Solid Cube		
8 Smaller Cubes		
8 Plate-Like Particles		

Density



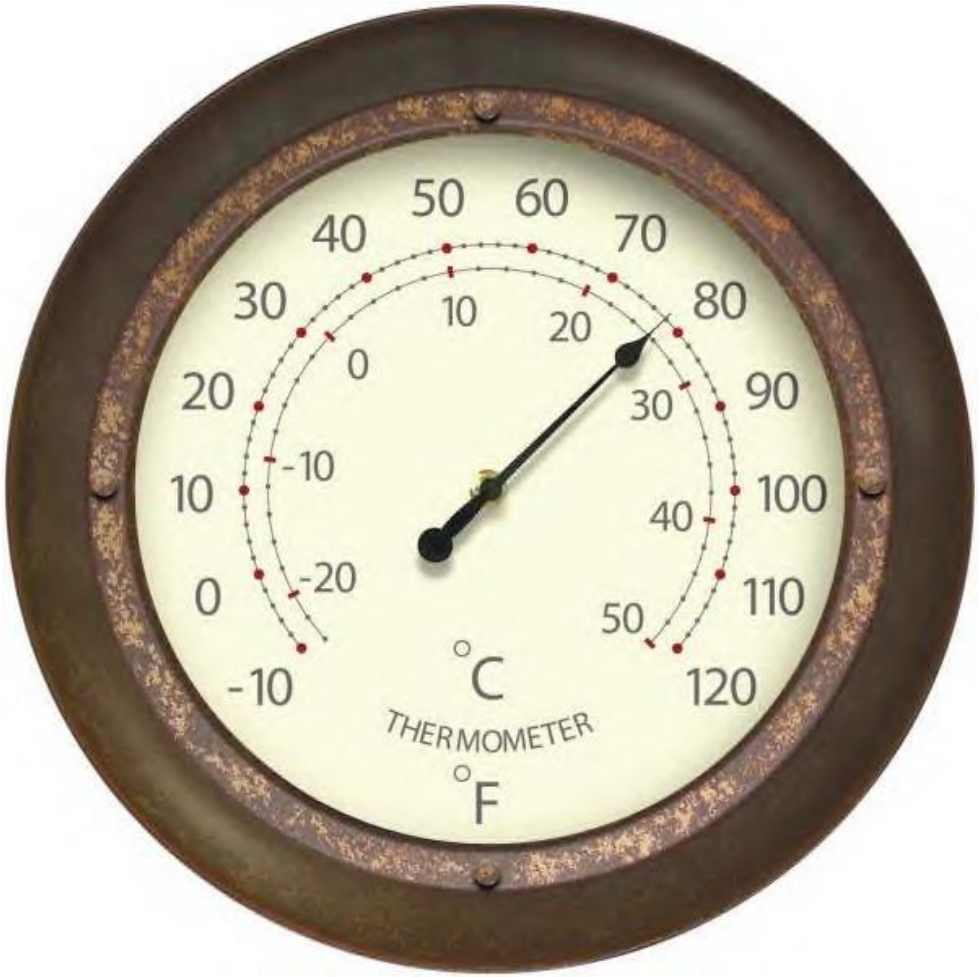
Weight-Strength-Mass Reduction Rates

Sunlight

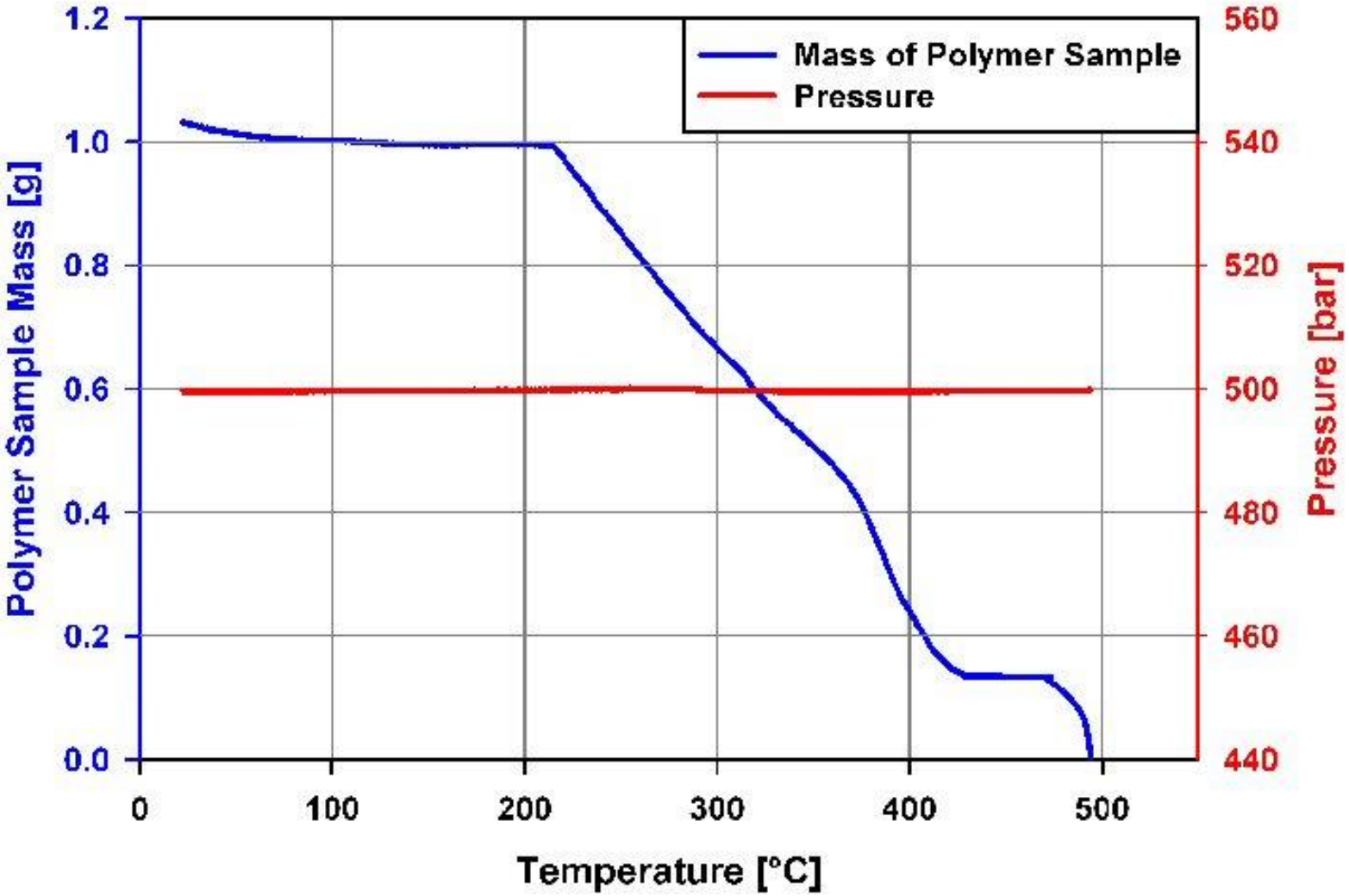


Ultraviolet rays cause some polymers to degrade.

Temperature

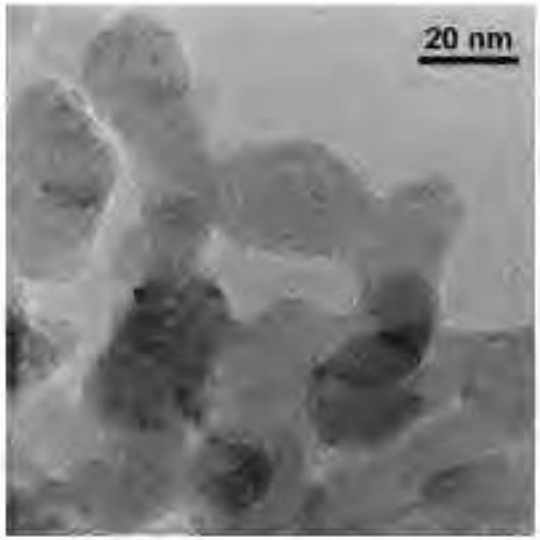


Temperature vs. Degradation

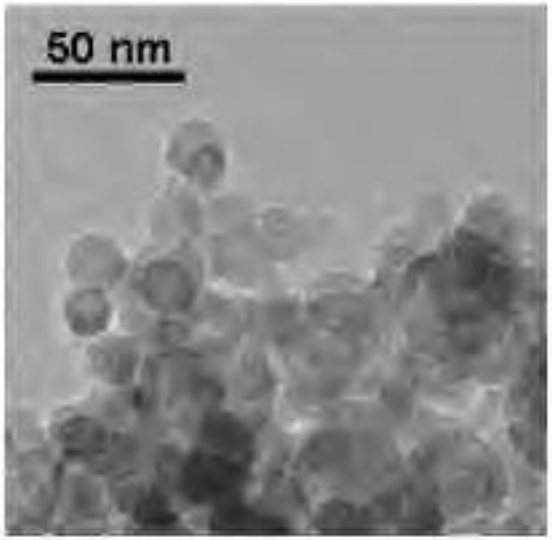


Presence of Water

Biodegradable Nanoparticles



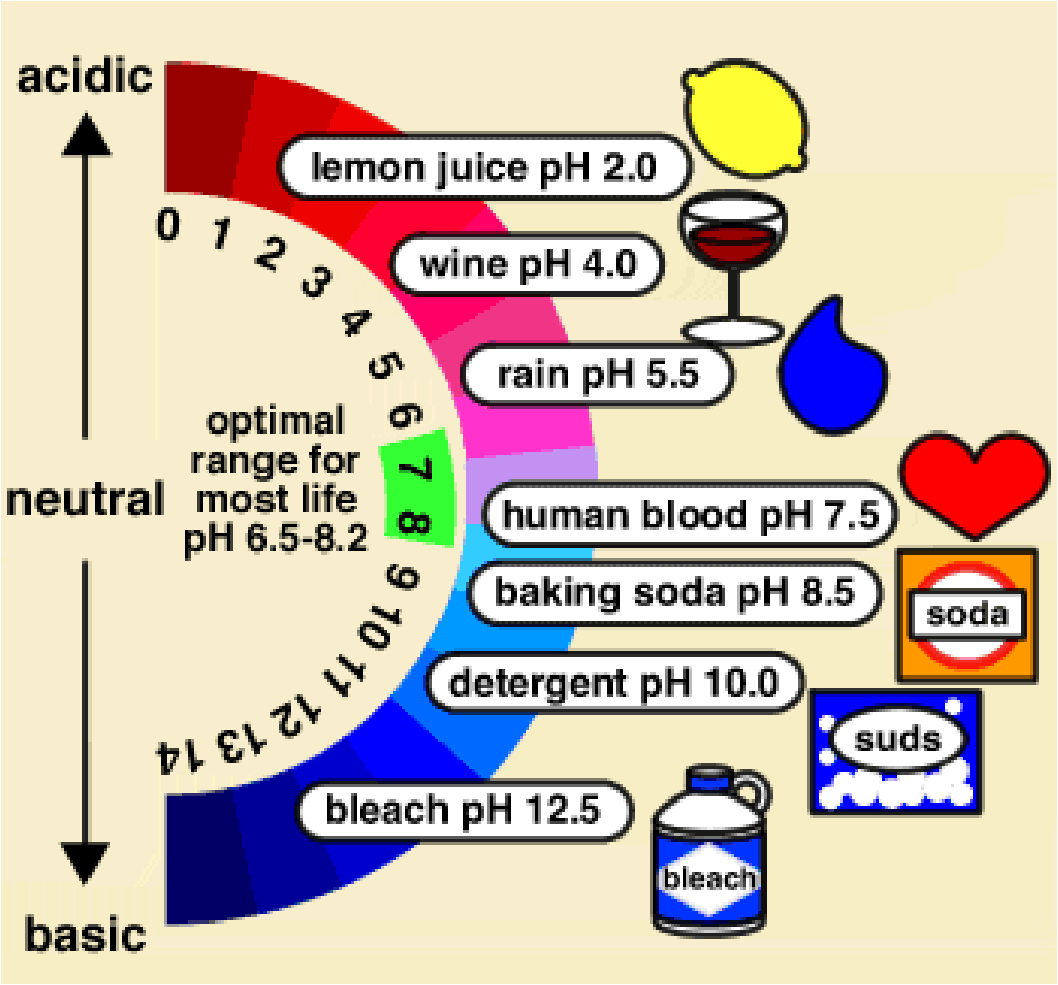
Amorphous Calcium Carbonate



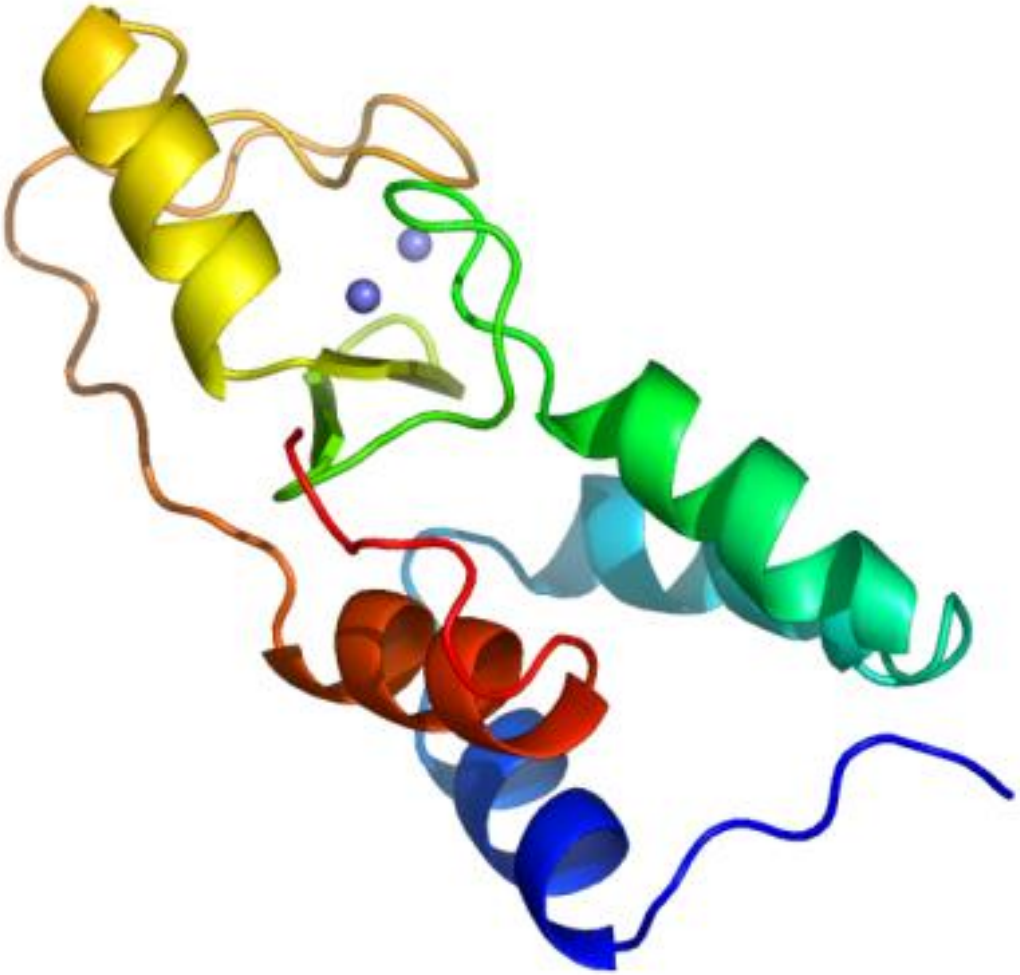
Amorphous Calcium Phosphate

Mineral fillers today are widely used in plastic production as degradable fillers that improve performance and reduce costs.

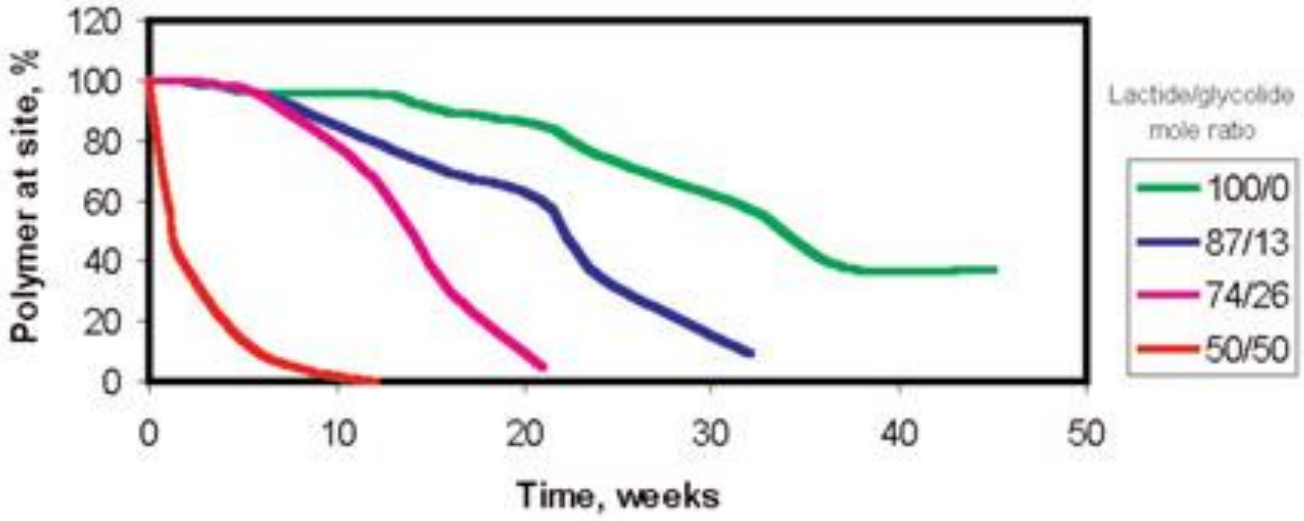
pH


acidic
neutral
basic
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
optimal range for most life pH 6.5-8.2
lemon juice pH 2.0
wine pH 4.0
rain pH 5.5
human blood pH 7.5
baking soda pH 8.5
soda
detergent pH 10.0
suds
bleach pH 12.5
bleach

Biodegradability Advances

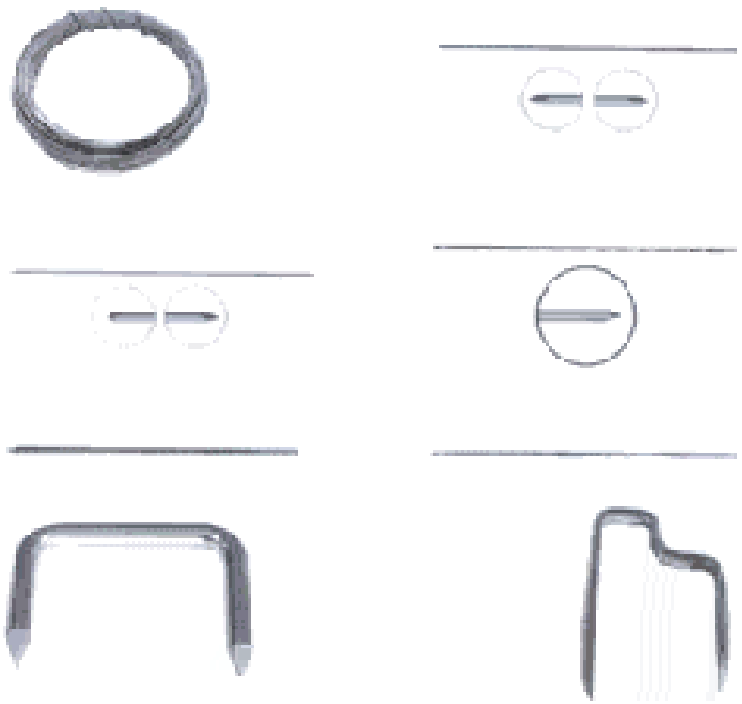


Biodegradable Sutures



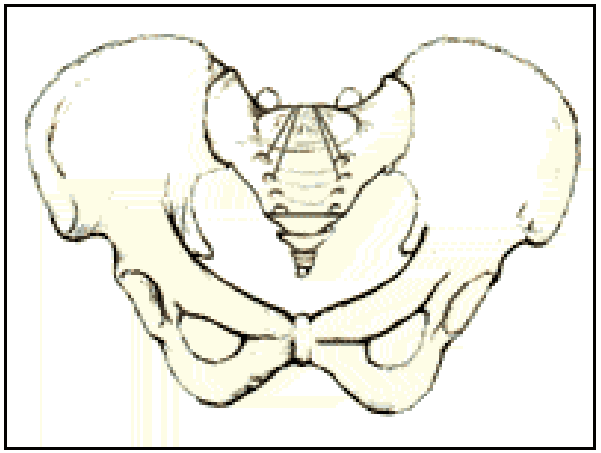
Eliminates the need for a second operation to remove the sutures.

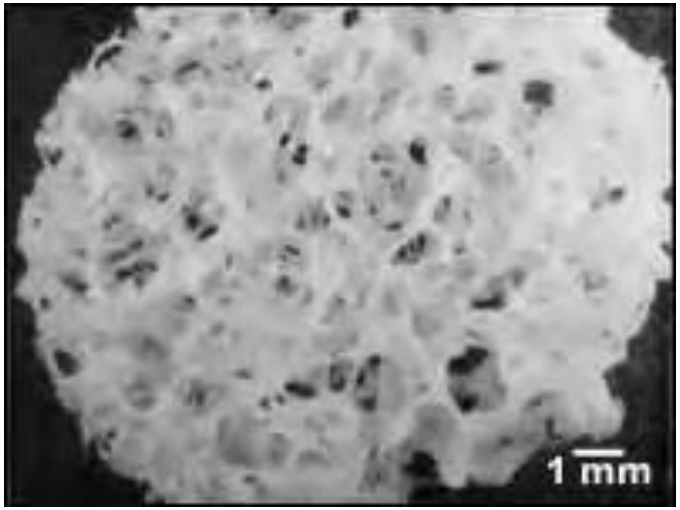
Orthopedic Pins



Orthopedic pins and screws are now being made of strong biodegradable materials.

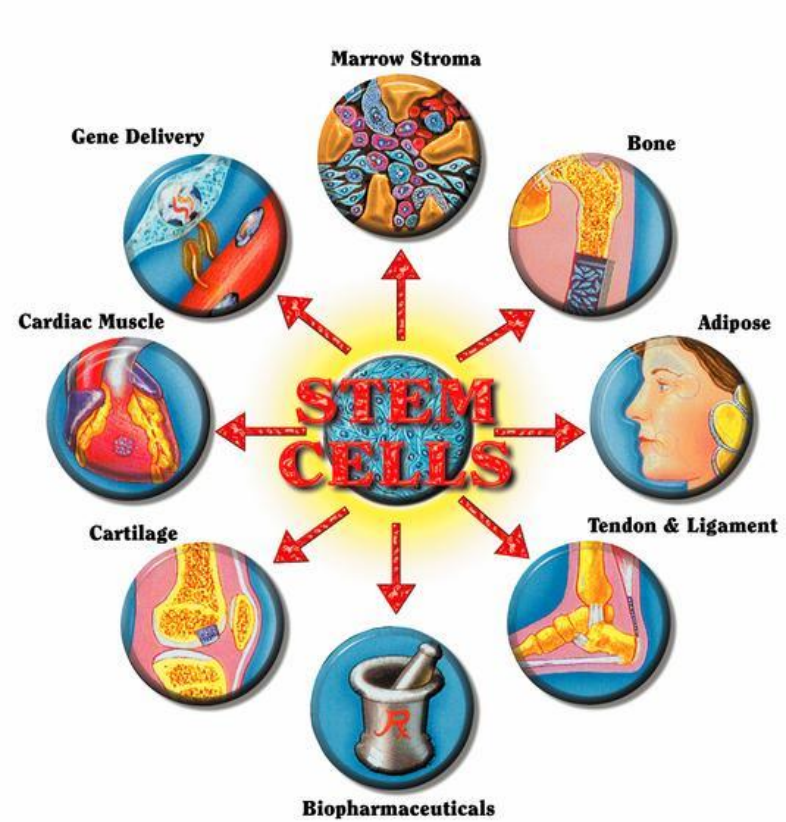
Trabecular Bone





Polymer Scaffold

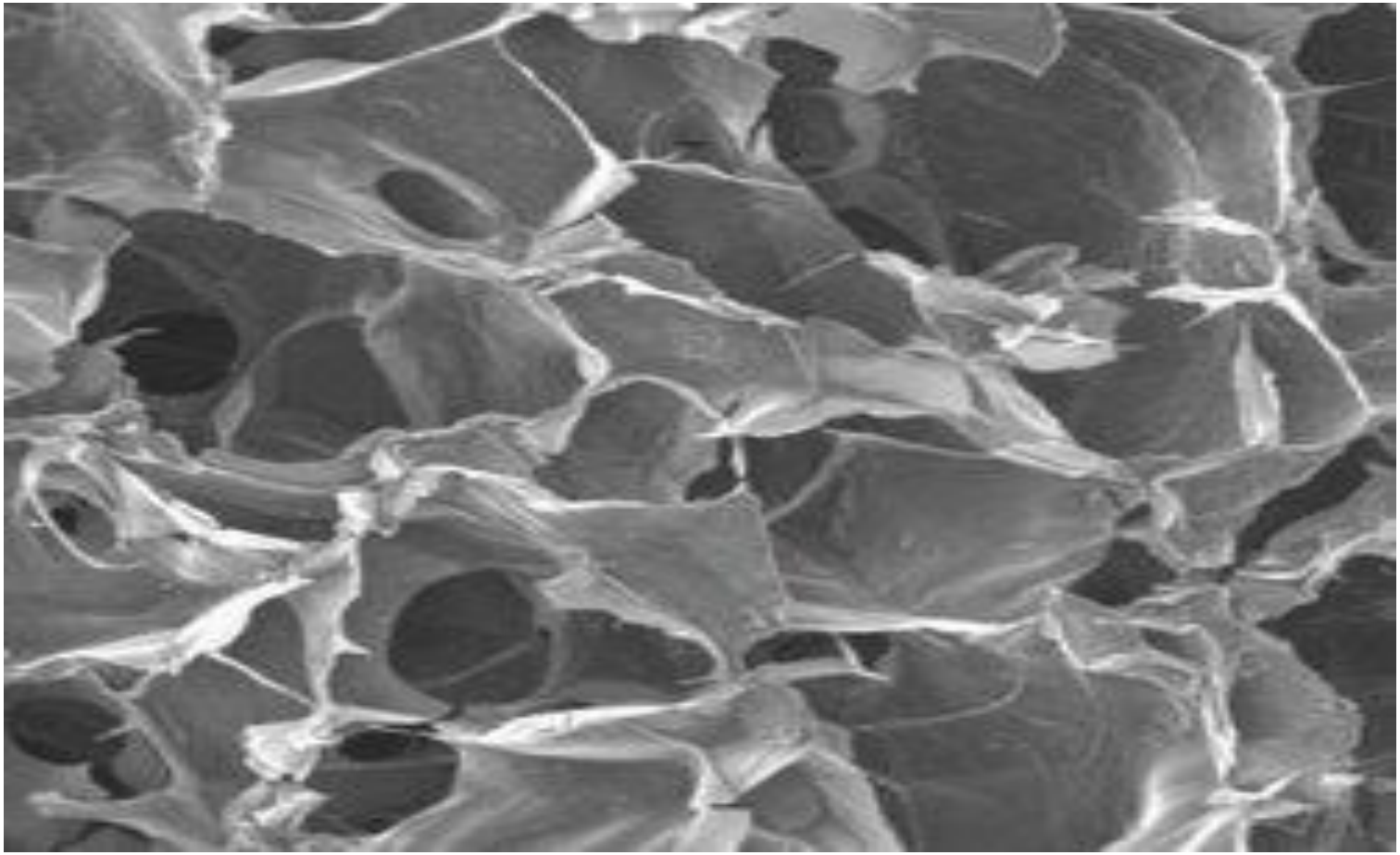
Stem Cell Research



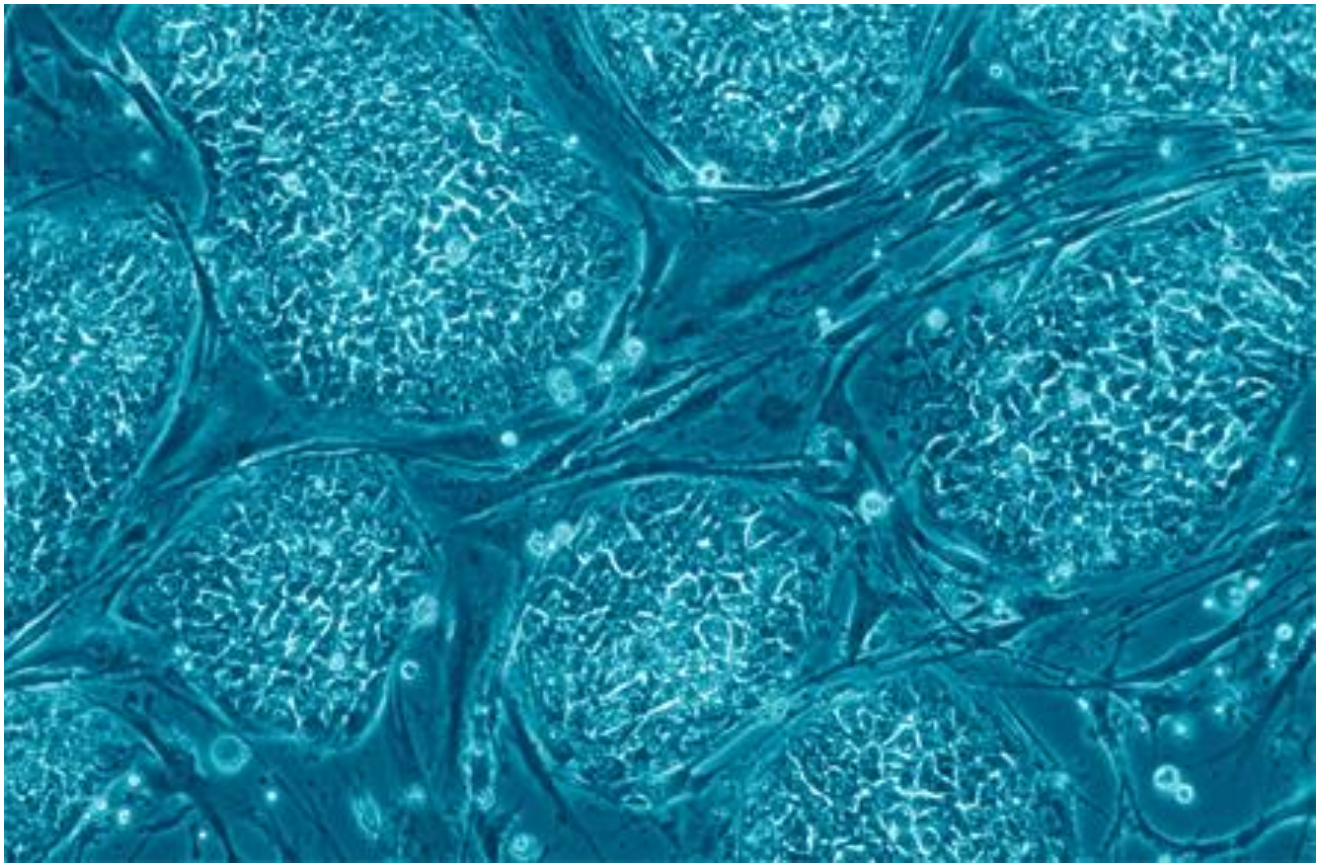
In 2005, medical researchers were shocked to discover that virtually all human embryonic stem cell lines were contaminated.

Animal byproducts used to line Petri dishes had left traces on the human cells.

If those cells had been implanted in a human body they likely would have been rejected by the patient's immune system.

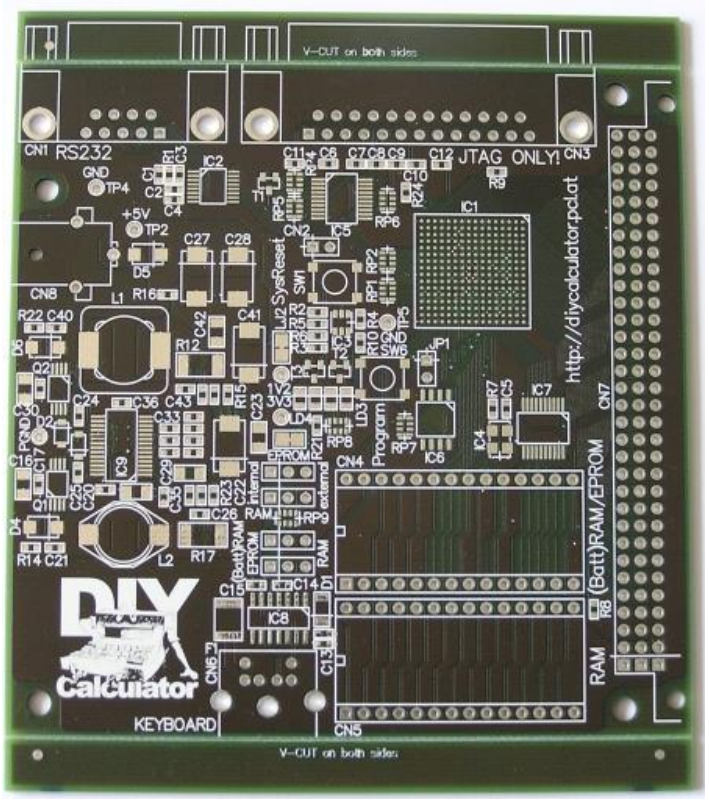


Scientists have now built a three-dimensional scaffold out of a natural material that mimics the binding sites for stem cells, allowing the cells to reproduce on a clean, biodegradable structure.



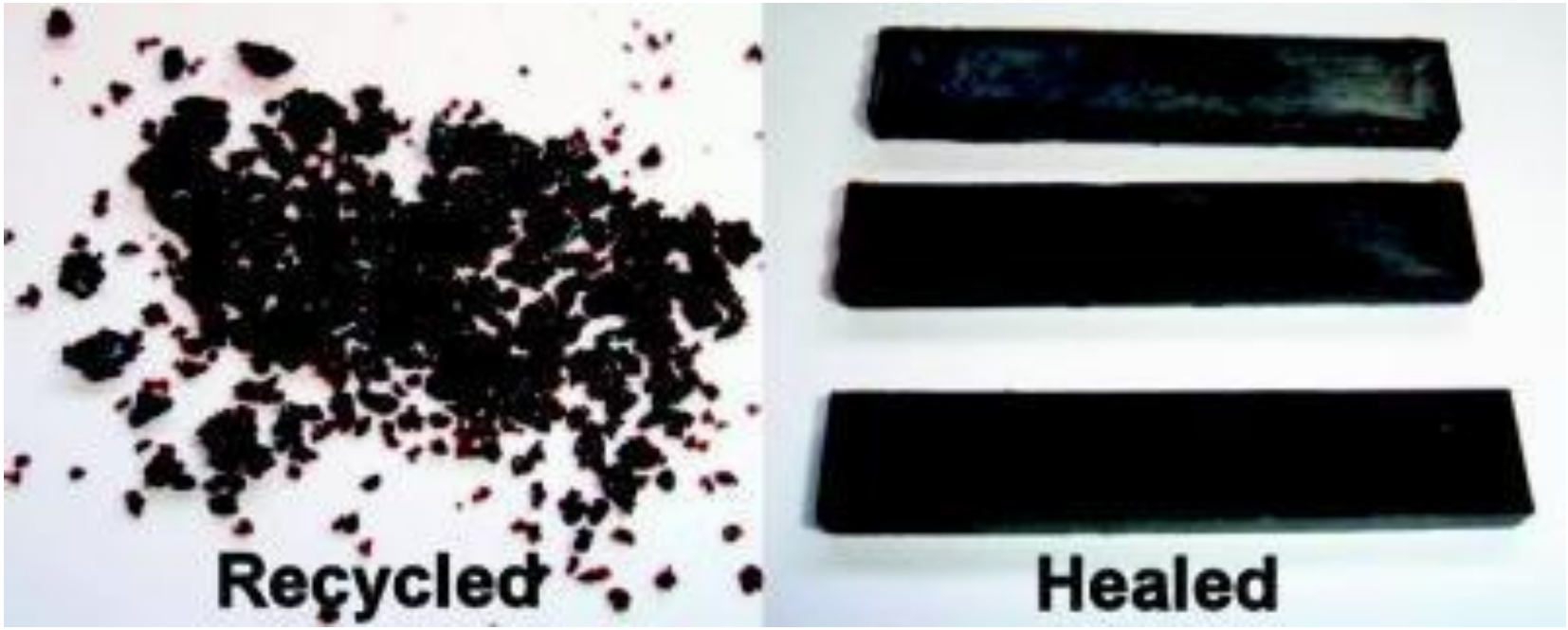
Researchers seeded the scaffold with 500,000 embryonic stem cells, and after 21 days the scaffold was completely saturated. These results show that human embryonic stem cells grow and multiply readily on the structure.

Self-Healing Biodegradable Polymer



Researchers in The Netherlands are reporting development of thermally self-healing polymeric materials for use in the first easy-to-recycle computer circuit boards.

The new type of thermosetting plastic that can be melted and remolded without losing its original heat-resistance and strength.

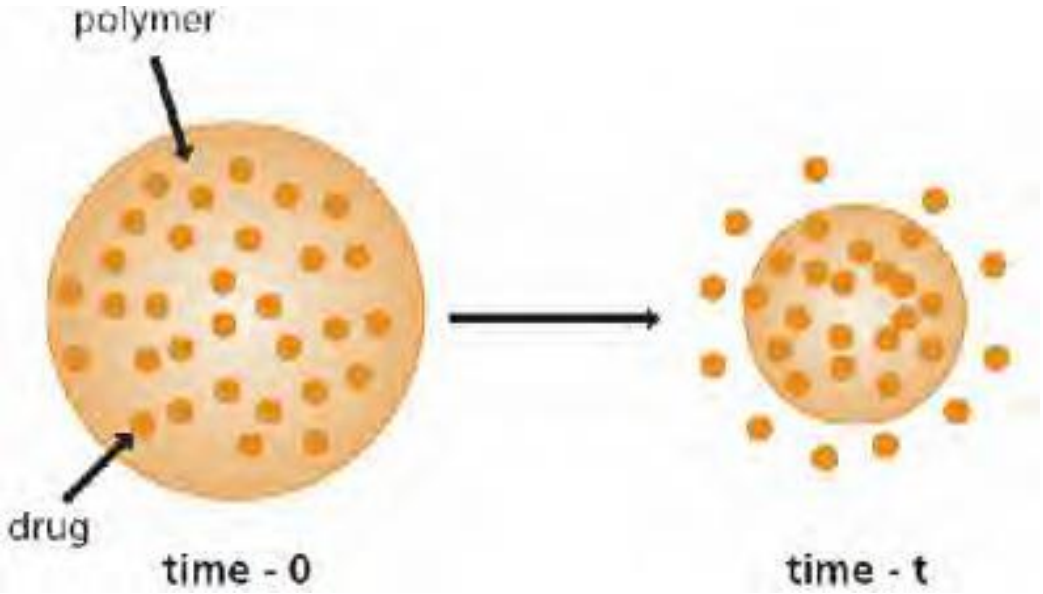


Tests show you could melt granules of the "self-healing" polymer and reform them into uniform, rigid plastic bars many times.

Drug Delivery System

One area of intense research activity has been the use of biocompatible polymers for controlled drug delivery.

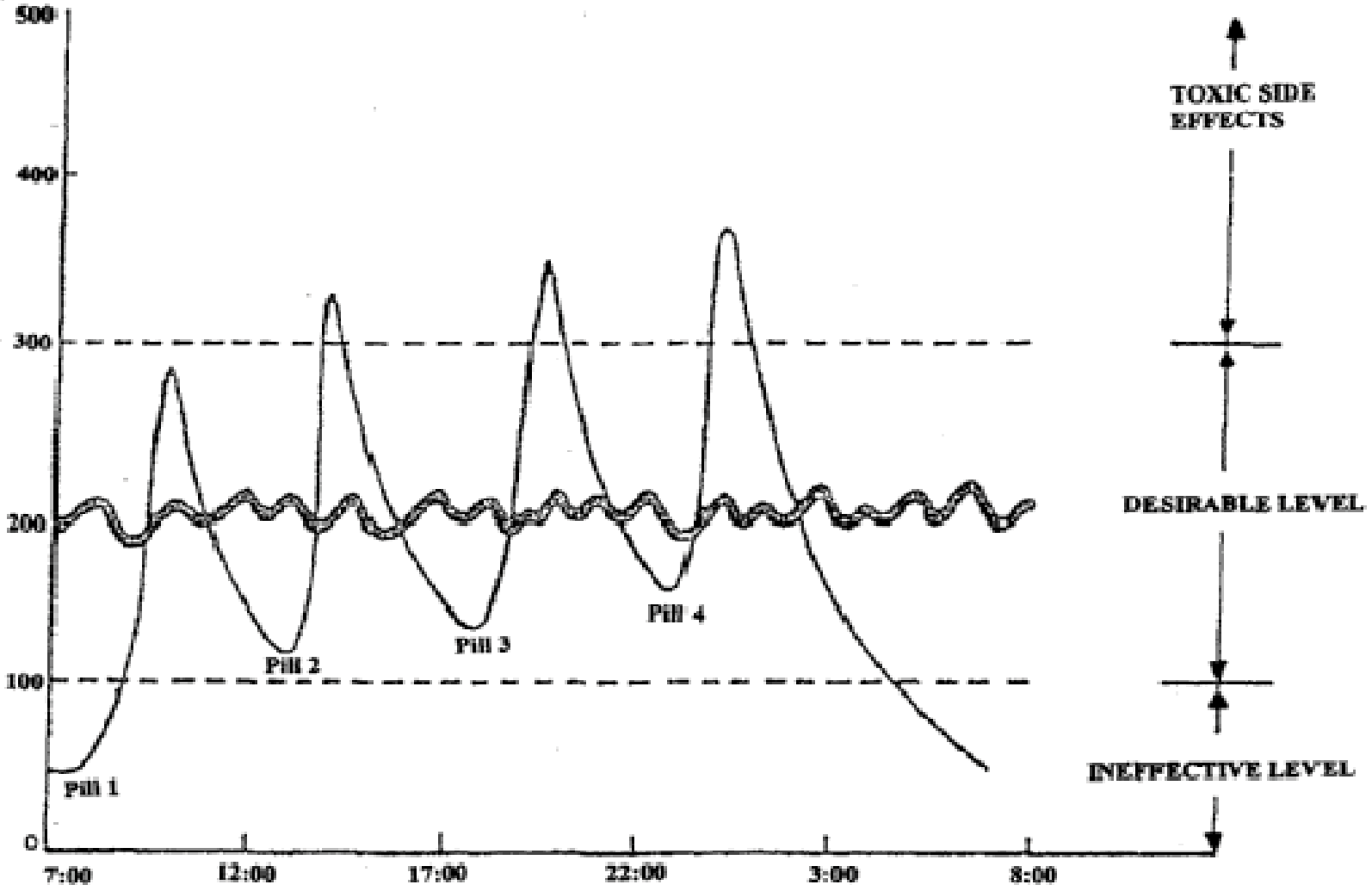
Drug Delivery System



Biocompatible polymer release rates can be determined by the design of the system and are nearly independent of environmental conditions.

Drug Delivery System

Localized delivery lowers the systemic drug level, reduces the need for follow-up care, preserves medications that are rapidly destroyed by the body, and increases patient comfort.

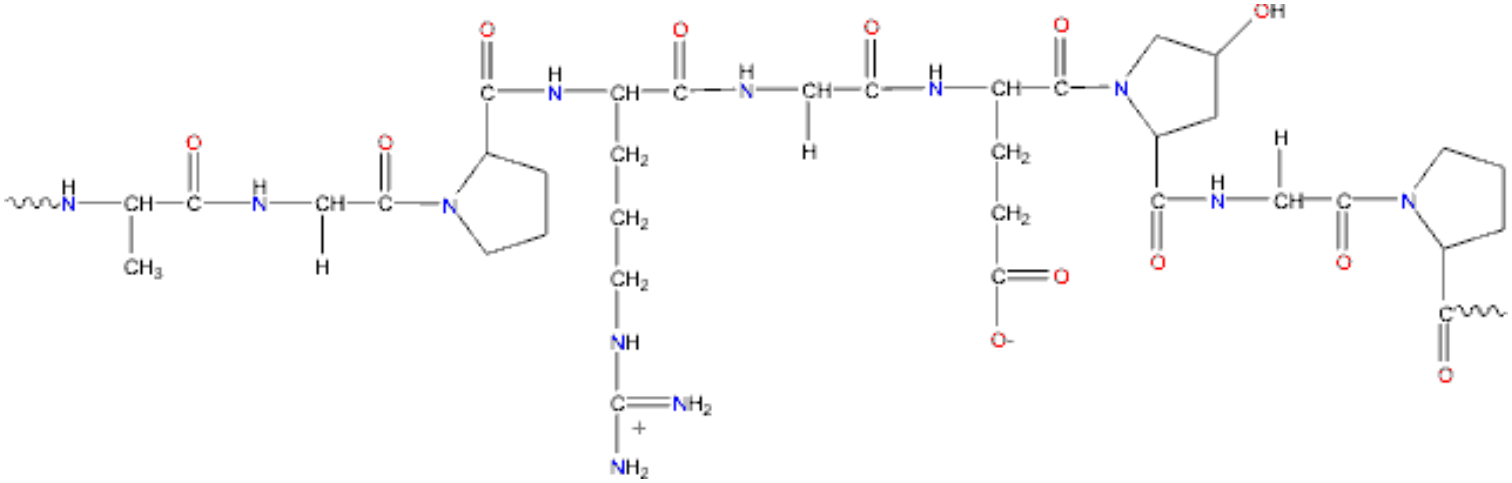


The goal of the controlled release devices is to maintain the drug in the desired therapeutic range with just a single dose.

Drug Delivery Systems

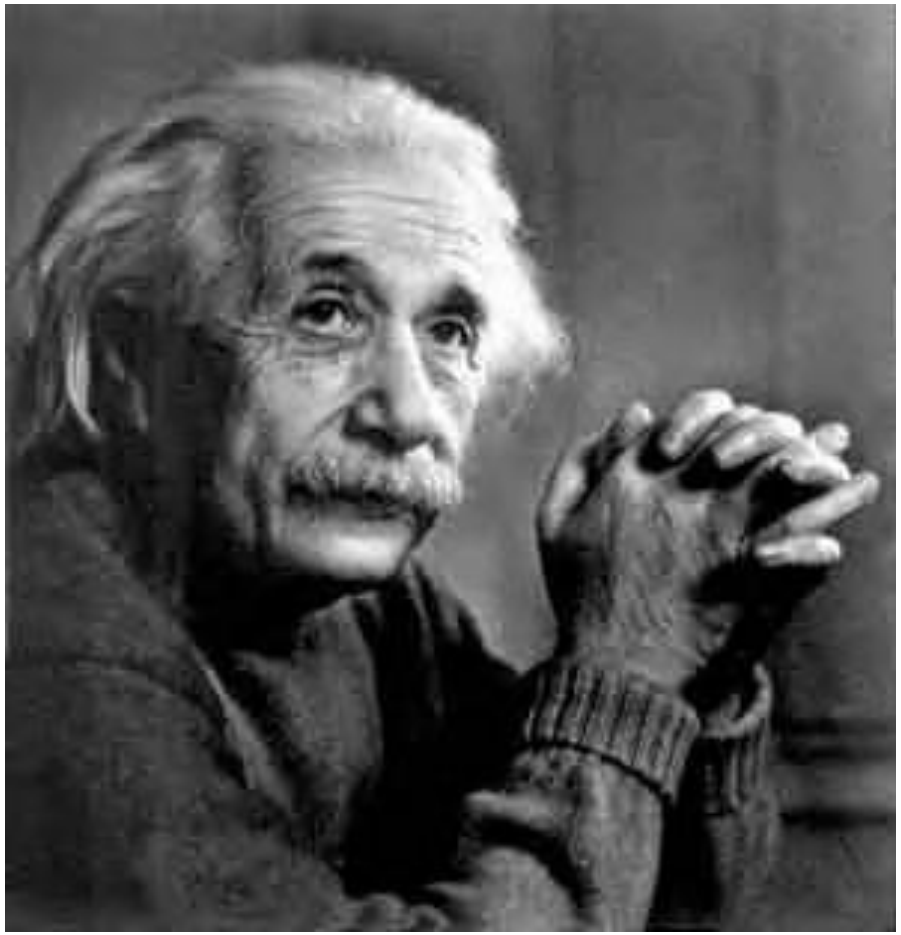
Gelatin has been the most used biocompatible polymer for controlled drug delivery.

Gelatin is a vitreous, brittle solid that is faintly yellow to white and nearly tasteless and odorless.

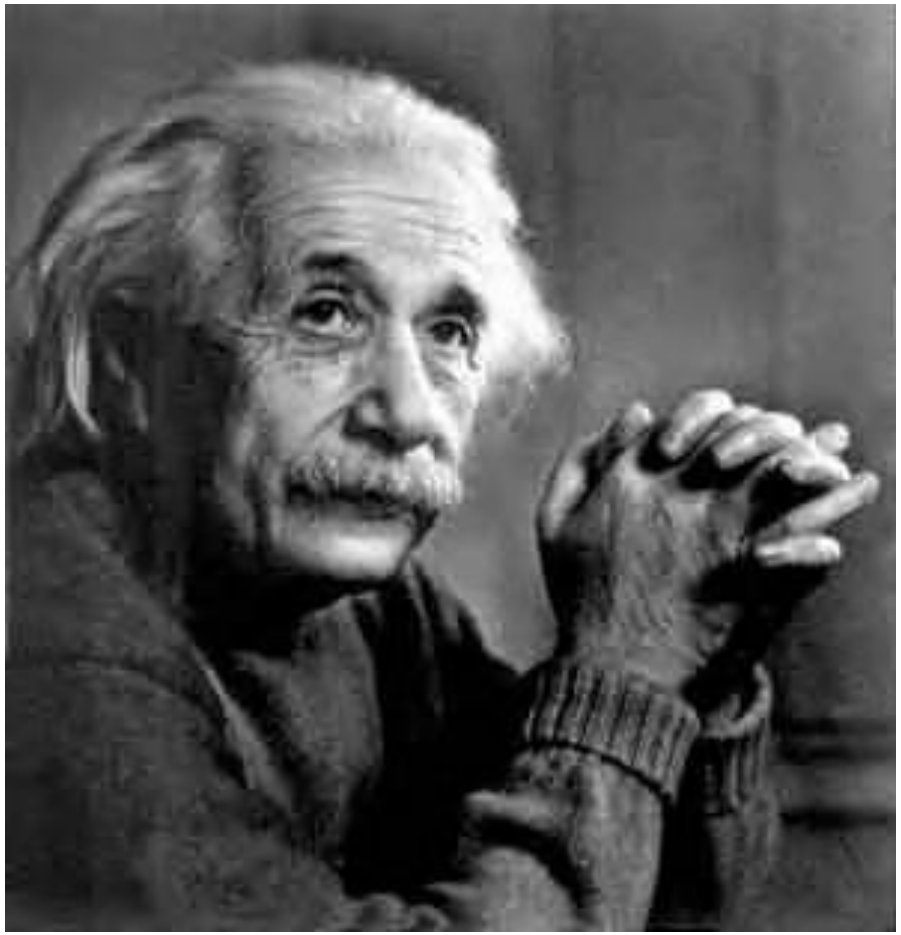


Gelatin contains 84-90% protein, 1-2% mineral salts and 8-15% water.

Lab: Making a Gel



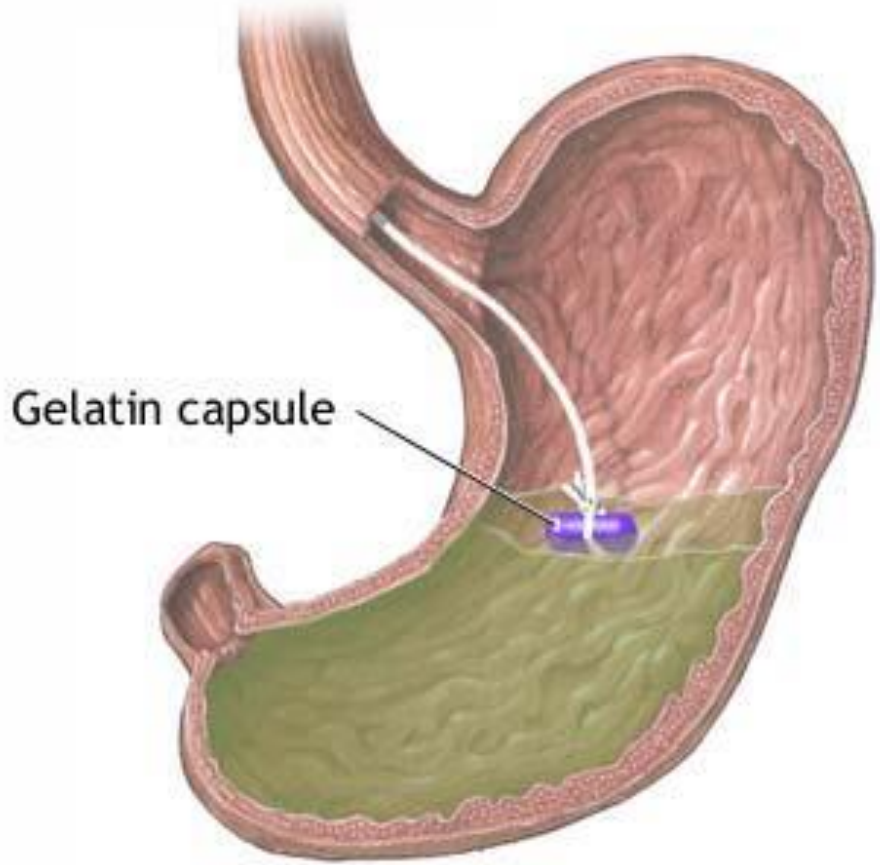
Lab: Gel Dissolve Rate



Lab: Gel Dissolve Rate

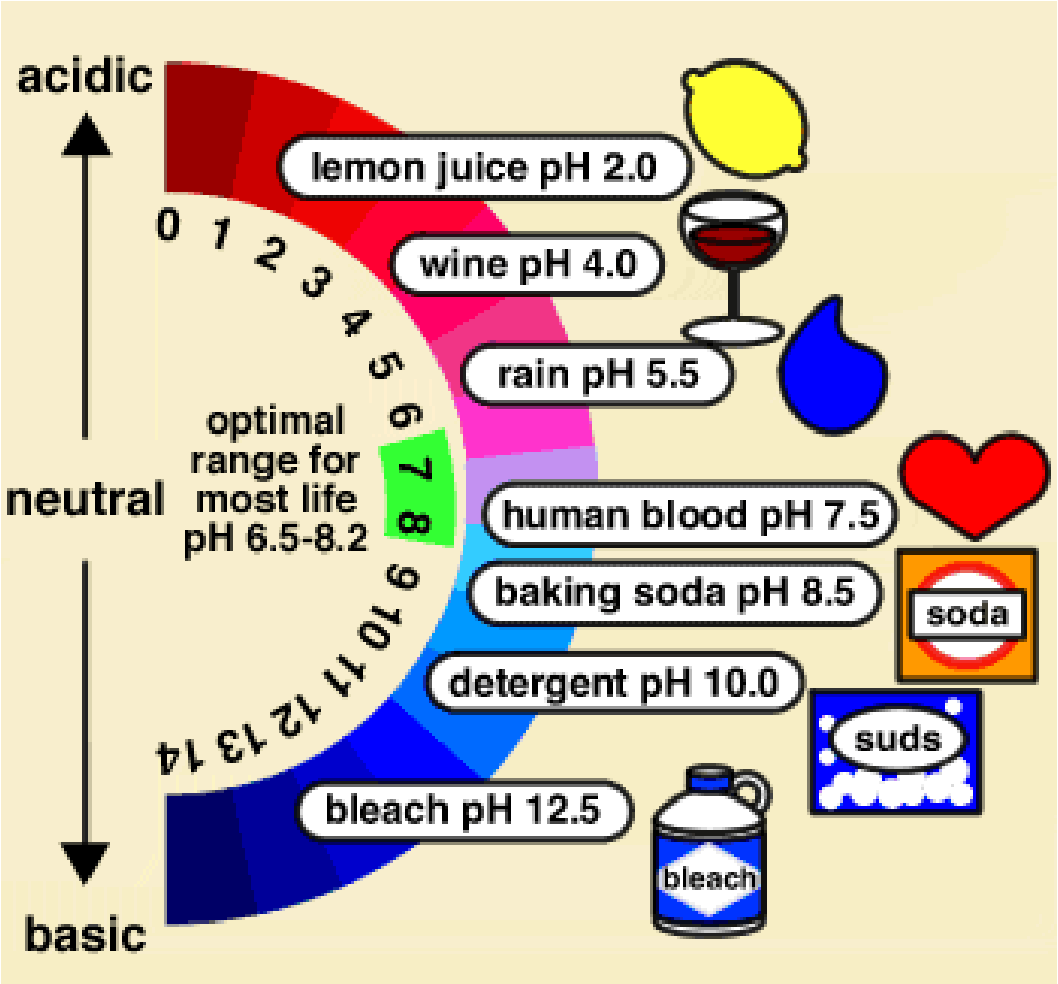
Data Chart

# of Caps	Dissolve Time (s)
8	
12	
16	
20	
24	
28	
32	



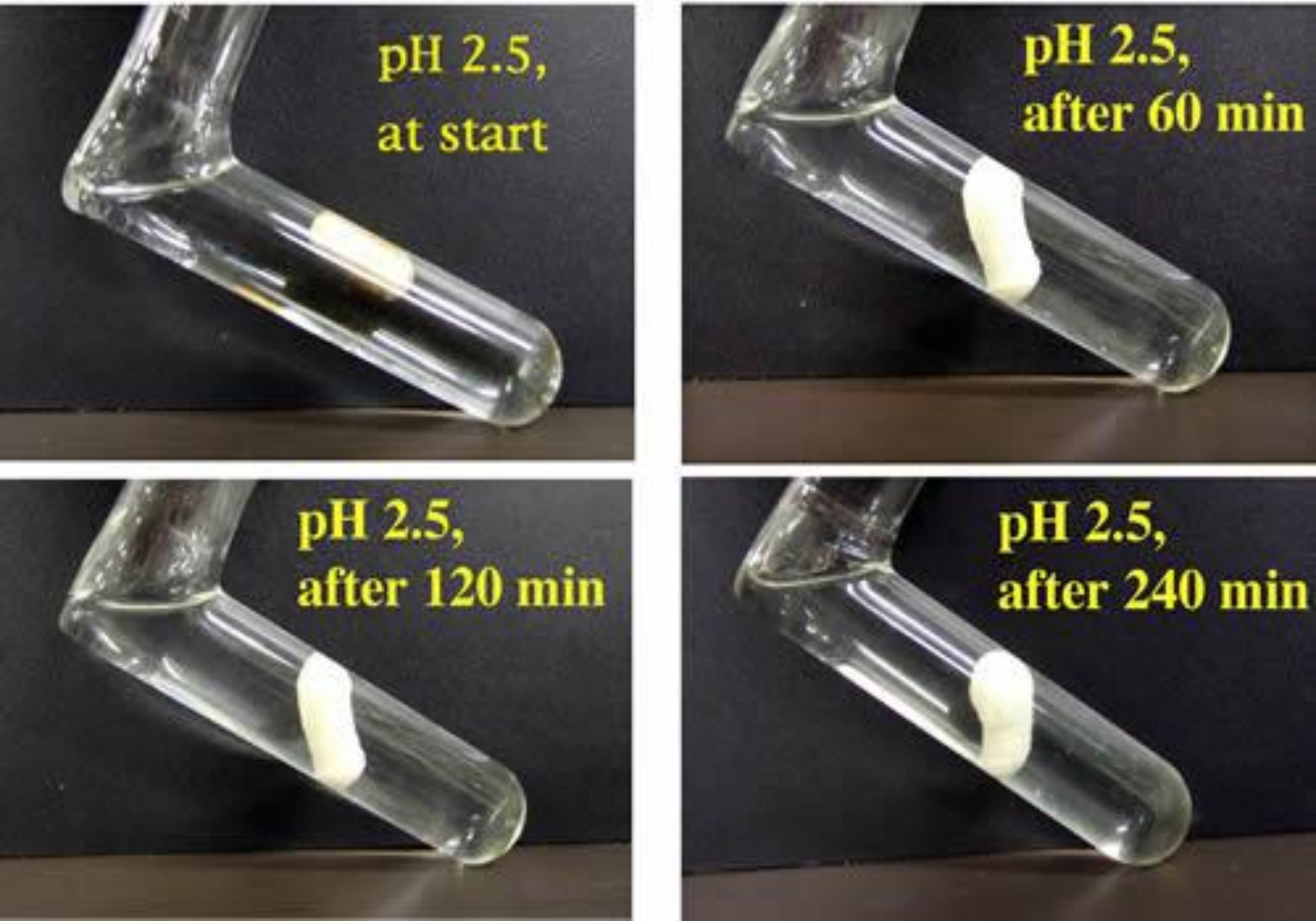
The challenge facing drug delivery system gel is can it smuggle its contents past the stomach and slowly release the drug into the blood later on where its needed!

pH = 1.5 to 3.5


acidic
neutral
basic
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
optimal range for most life pH 6.5-8.2
lemon juice pH 2.0
wine pH 4.0
rain pH 5.5
human blood pH 7.5
baking soda pH 8.5
detergent pH 10.0
bleach pH 12.5
soda
suds
bleach

Food spends between 30 minutes and 2 hours in the stomach!

Fig.2 Resolvability of Probiotic GFR Capsules in low pH solution (pH 2.5)



SMALL INTESTINE

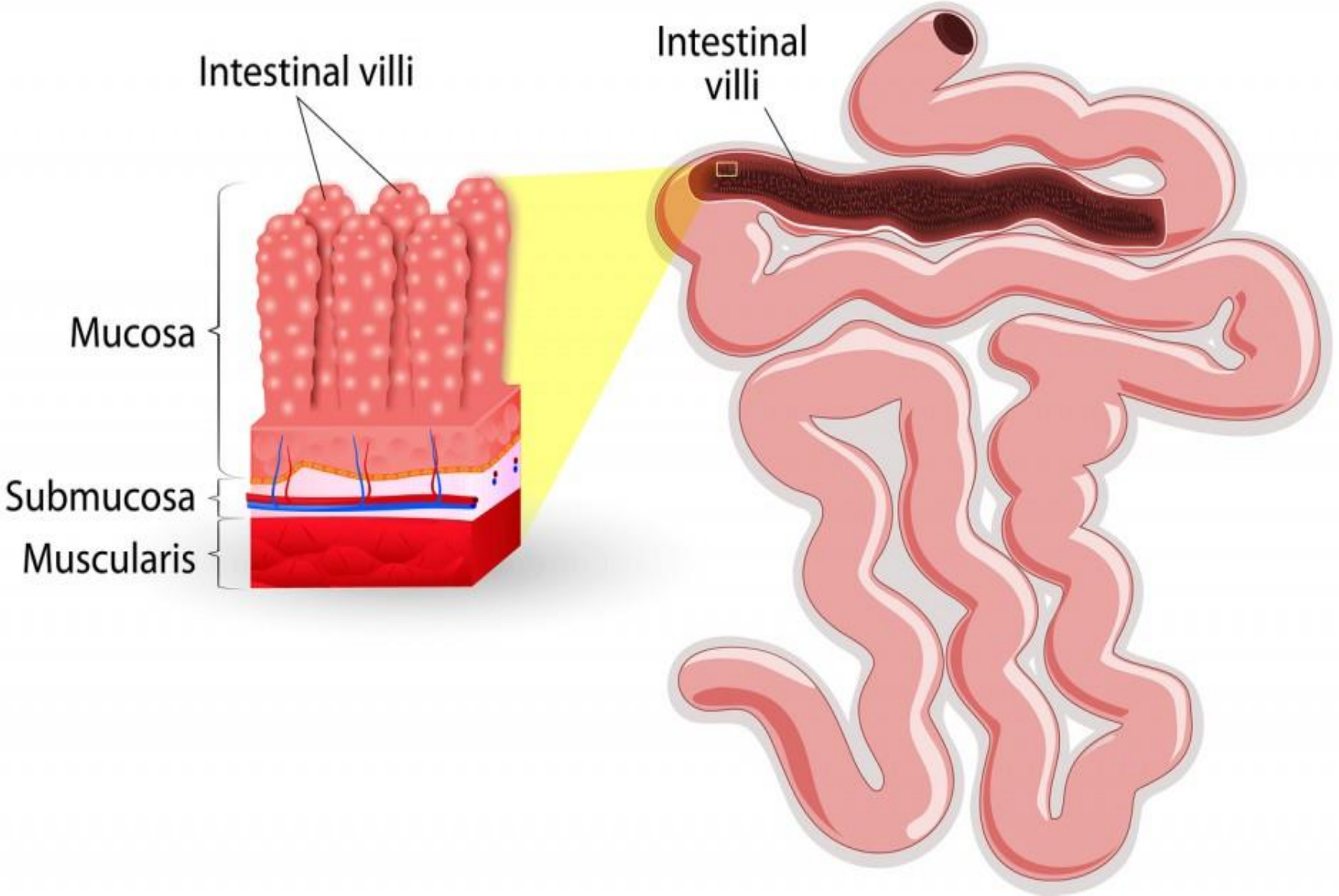
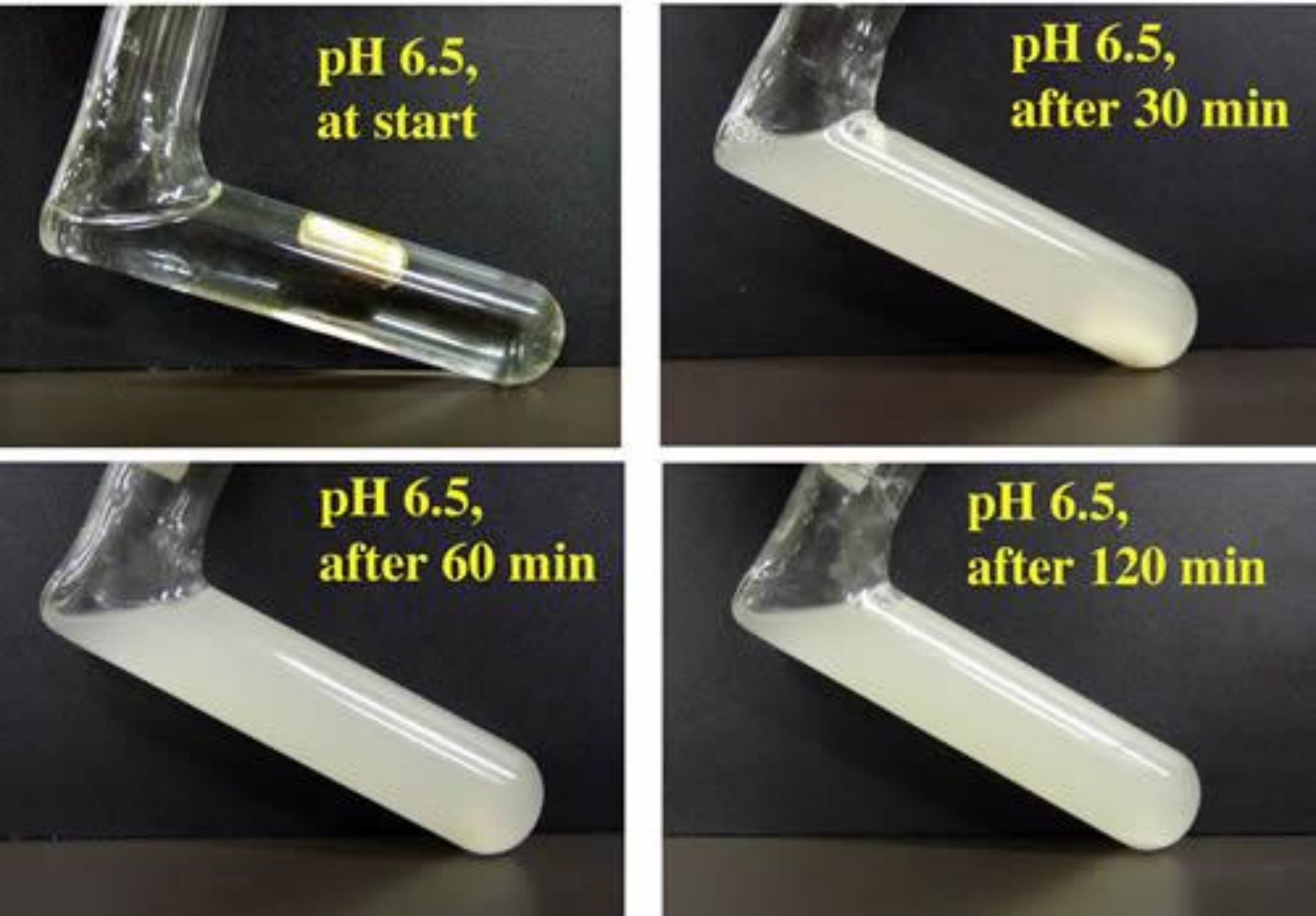
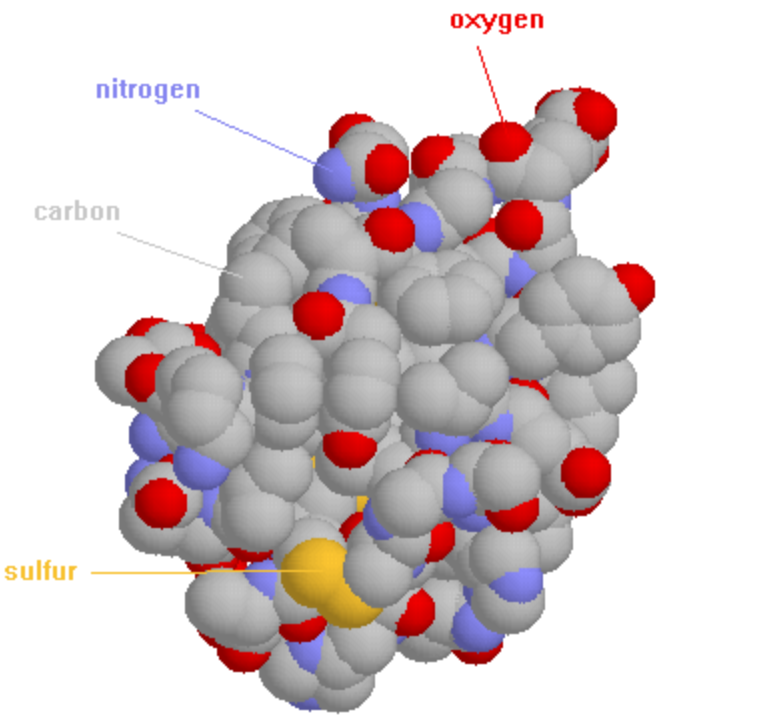


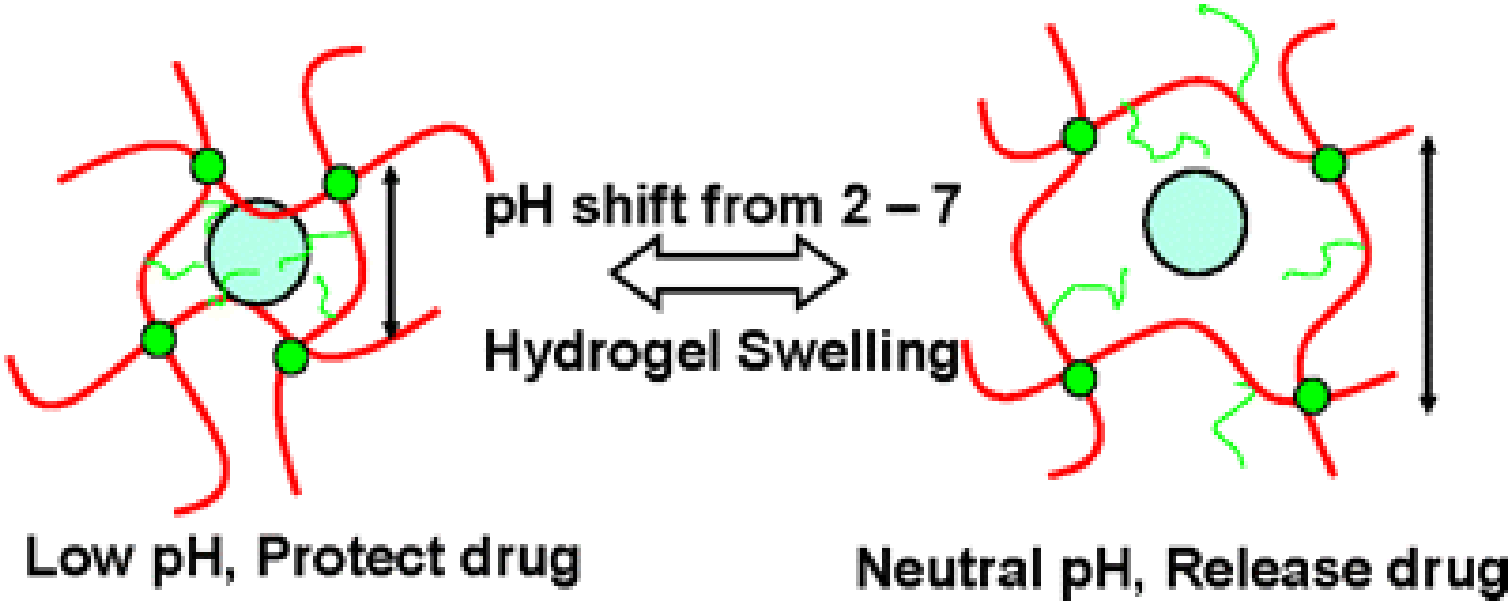
Fig.3 Resolvability of Probiotic GFR Capsules in neutral pH solution (pH 6.5)





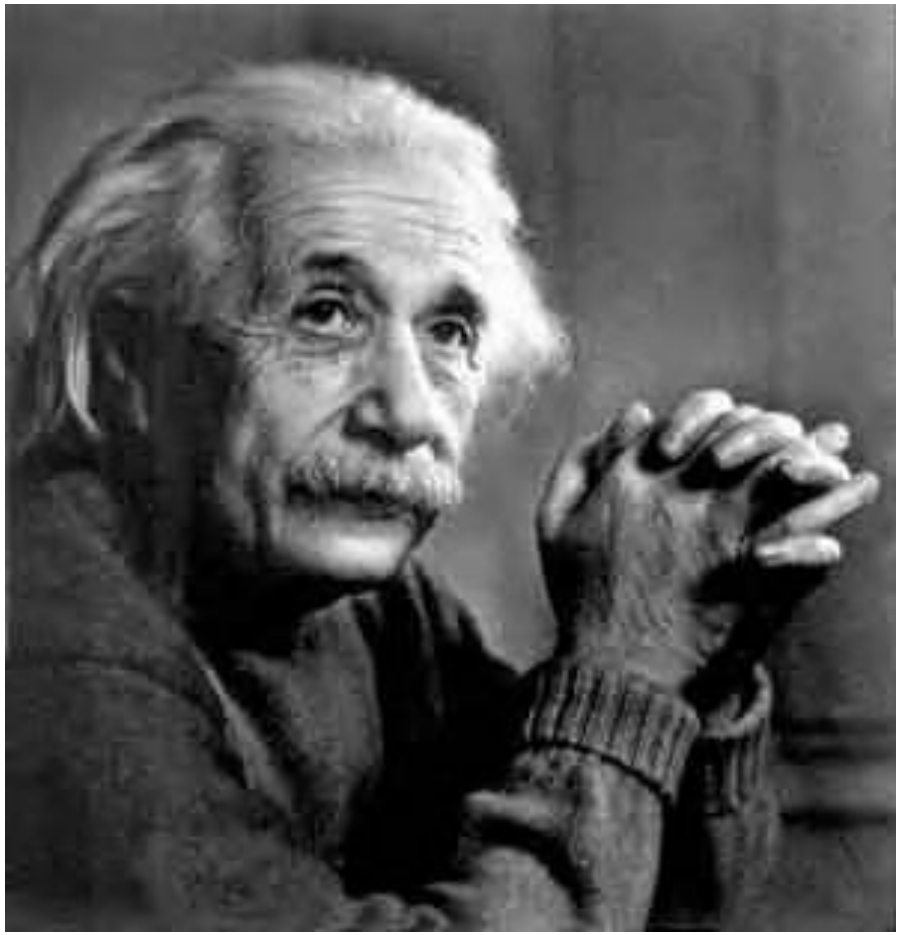
INSULIN (CPK colors)

Stomach-proof gel hints at jab-free diabetes treatment



Insulin-loaded gel was able to cope with acidic stomach-like conditions for an hour, but when in less acidic conditions like those found in the intestines, the gel swelled and release its payload.

Lab: Gel in Acid

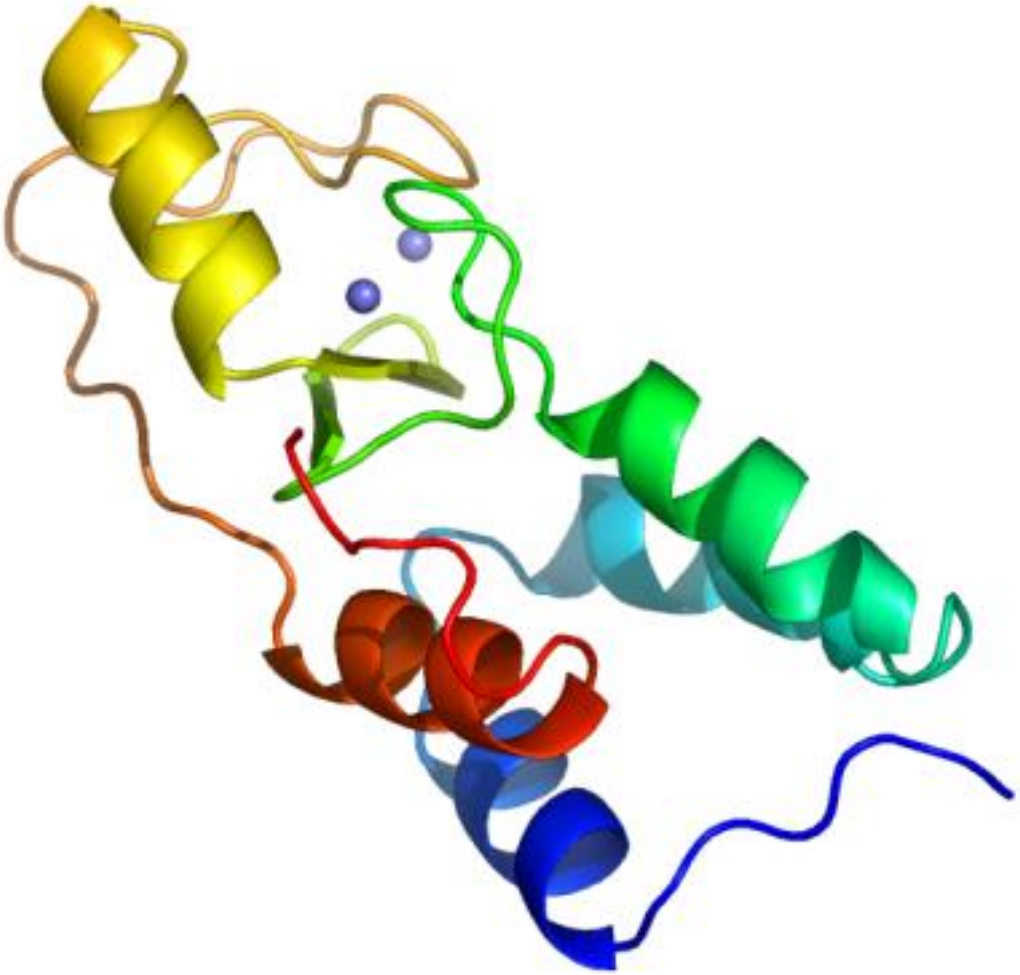


Lab: Gel in Acid

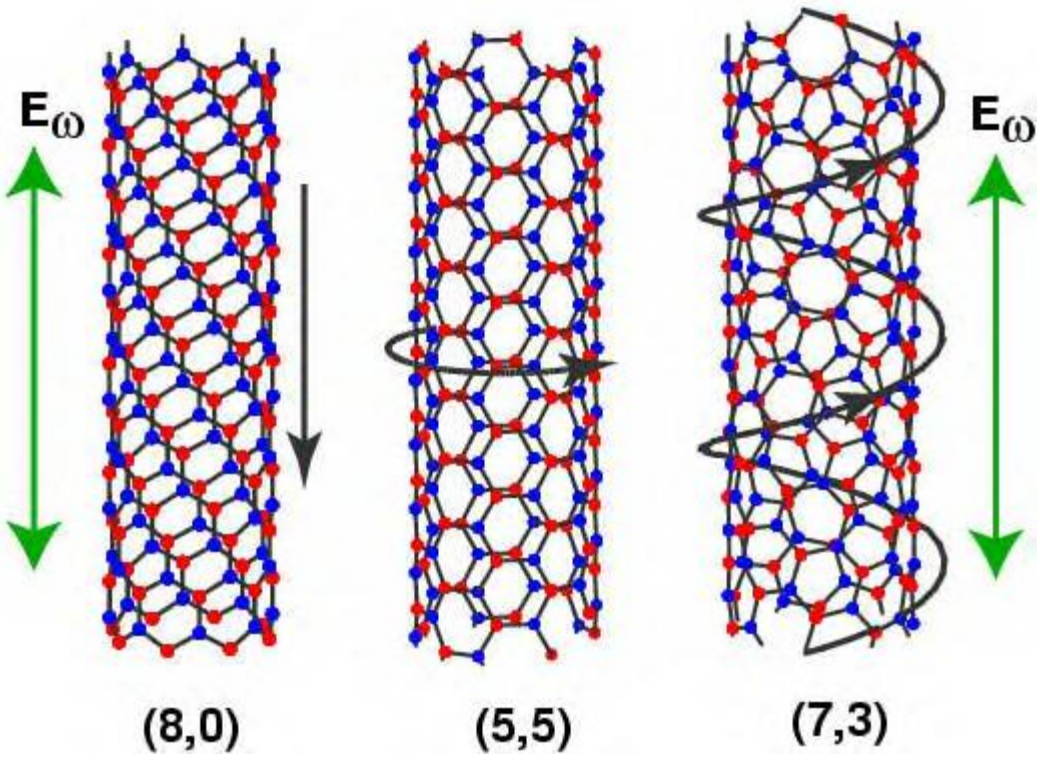
Data Chart

# of Caps	Dissolve Time (s)
4	
8	
12	
16	
20	
24	
28	

Biodegradability Advances

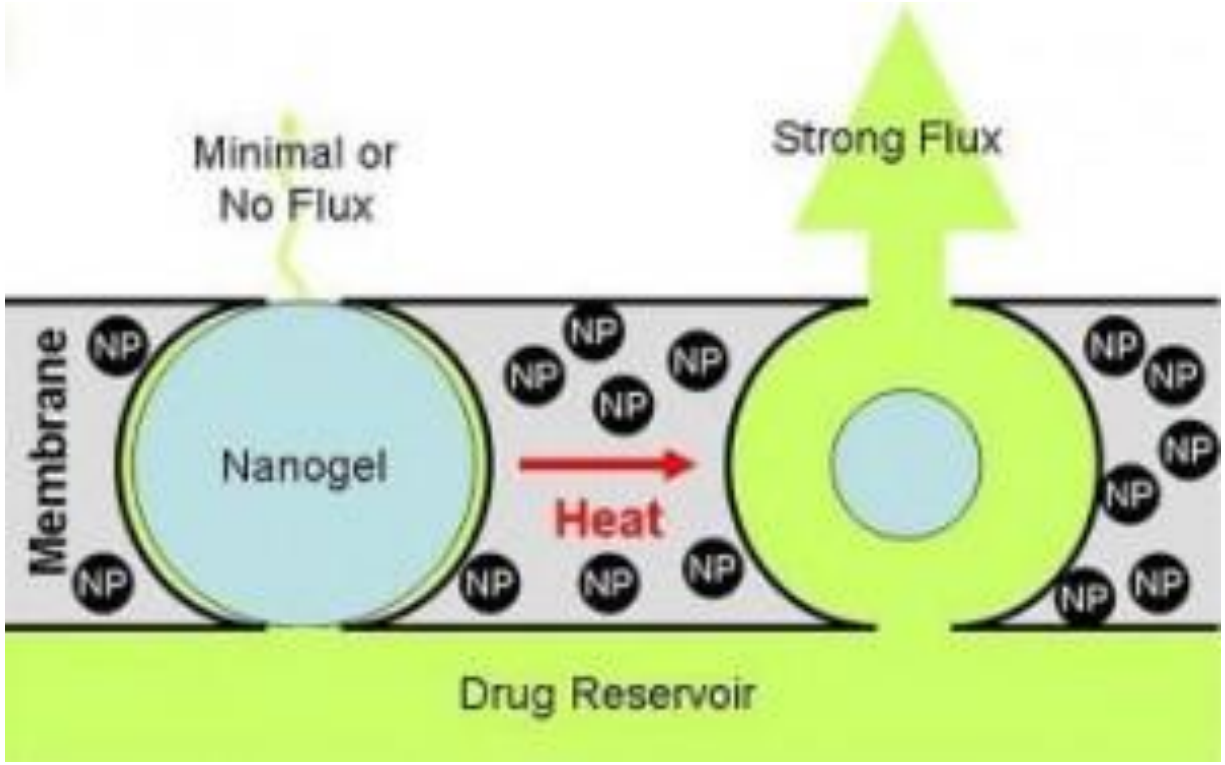


Electrical Conducting Nanotubes



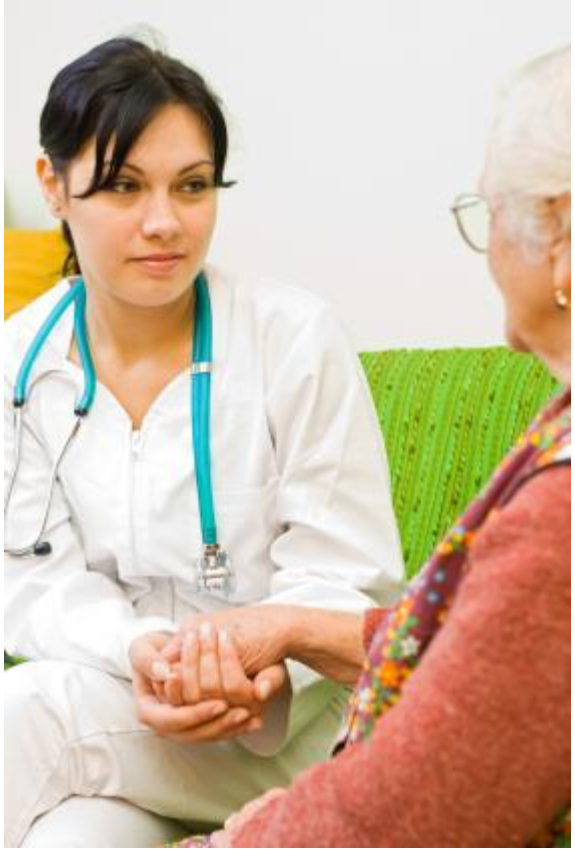
Nanotubes made of a polymer that conducts electricity will release drug in response to an electrical signal.

Electrical Conducting Nanotubes



Deposited nanotubes on a microelectrode could yield implantable drug delivery devices capable of treating tumors repeatedly on a programmed time schedule.

Electrical Conducting Nanotubes



These would allow patients or their physicians to determine exactly when drugs are delivered, and in what quantities.