I. Brainstorm

Have you ever wondered how diapers work? What are they made of and how are they able to hold so much liquid inside? Today, we're going to look inside a diaper to find and investigate the secret ingredient!

II. Diaper Experiment

1. Grab a diaper and carefully cut through the inside lining. Remove the plastic lining and collect the cotton-like material inside the lining in a plastic bag.
2. Seal the plastic bag, blowing in to it so that it fills up with some air. Vigorously shake the bag until you see powder collecting at the bottom.
3. Pour the powder into a cup – you may want to use only half of it so that its easier to work with. We've now isolated the secret ingredient.
4. Now it's time to mix the powder with water to see what happens. Pour approximately ½ cup of water into the cup of powder. Add more as necessary!
5. After about 30 seconds, observe that the water has changed — it's no longer a liquid… it's a gooey solid!
   What is the powder doing? Can you think of anything similar? What do you think it's made of?

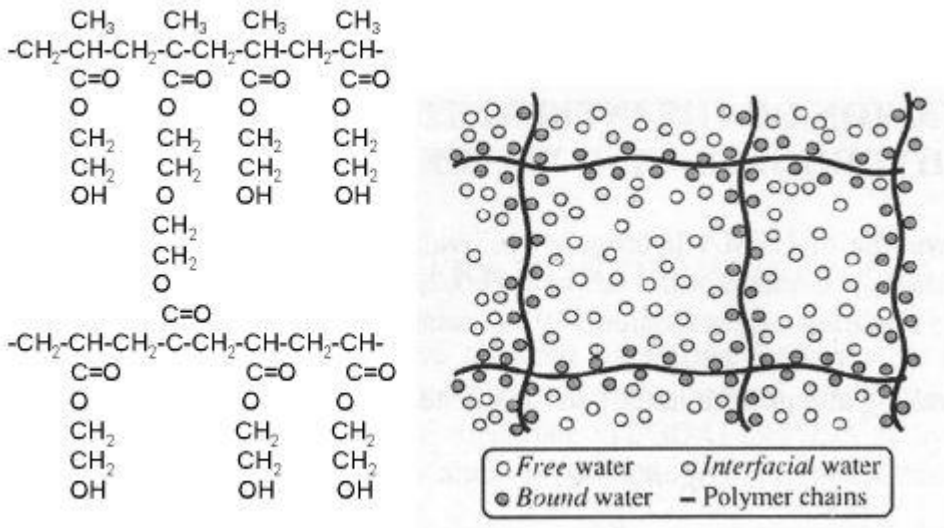
III. Hydrogels!

What are hydrogels?

- Hydrogels are a class of polymers that can absorb large amounts of water without dissolving. This is due to the physical or chemical cross linkages of hydrophilic polymer chains. The hydrophilic polymers contain 99% water and are highly flexible.
- Hydrogels mimic many of the properties of natural tissue so they are highly biocompatible.
- Hydrogels can be made porous or dense depending on usage requirements by altering their composition.
- Hydrogels can be prepared from monomers, prepolymers, or existing hydrophilic polymers. These polymers are composed of oxygen, hydrogen, carbon and sometimes nitrogen bonds.
- Note: Other types of absorbent polymers/gels will absorb other liquids.

Here’s a picture of their actual chemical bonds:

PEGDMA-co-PHEMA



IV. “Degradation” of Hydrogels

New hydrogel classes have recently developed in a way that allows biodegradability. These gels retain their original mechanical strengths and physical properties. They are engineered to react to the environment in which they are placed, so different gels will degrade under different conditions and at varying rates.

Let’s go back to the hydrogel found in diapers and see how they degrade!

1. Put the hydrogel from Part 1 back into the cup and add a spoonful of salt.
2. Stir the mixture until you notice a change
3. Observe that the solid compound has dissociated back into water and the powder!

So, the hydrogels found in diapers degrade when placed in salt water. Hairgel is another hydrogel that also degrades in the presence of salt (Try it!). Many hydrogels degrade when placed in ionic solutions (such as salt). Others degrade in the presence of certain enzymes.

There are many important applications of hydrogels in bioengineering. Can you think of some? Here are some pointers to get you started:

- They are full of water – can they help keep something hydrated?
- Their network of polymers allow us to insert other molecules that can be placed inside
- They are highly biocompatible

V. Drug Eluting Hydrogels

- One of the most important applications of hydrogels (in terms of biotechnology) is a **controlled drug delivery device.**
- A drug delivery device is a polymer (in the case of a hydrogel) combined with a drug in such a way that the drug can be released from the polymer in a predesigned manner.
- The release of the drug is controlled by:
  - Diffusion and/or
  - Degradation of the hydrogel
- The release of the drug may be:
  - constant over a long period,
  - cyclic over a long period,
  - triggered by the environment or other external events such as the change in pH.
- These devices are often implanted directly onto the tissue affected by the given disease.
- Hydrogels are great candidates because they are highly biocompatible, flexible and easily manipulated into behaving a certain way. Most importantly, they are biodegradable, so once they are implanted, another surgery is not required to remove them after the drug therapy has been completed.
- Advantages to using a controlled drug delivery system as opposed to systemic delivery (i.e. pills):
  - Eliminates potential for under- and over-dosing
  - Targets a specific area
  - Maintains drug concentration levels within a certain range
  - Allows consistent drug delivery over a long period of time with fewer invasive administrations
- Disadvantages of using such a system:
  - Possible toxicity or nonbiocompatibility
  - Undesirable products of degradation
  - Surgery required to place and remove implant
  - Higher cost as compared to traditional methods
- Polymers such as polyacrylamide are currently used in the drug delivery system because it is chemically inert and do not degrade to produce impurities that may be harmful to the human body.

Now, we're going to see how drug delivery devices work using Jello and food coloring to model a simple system

- In this system, the Jello acts as the hydrogel and the food coloring is the drug to be delivered
- The device is sensitive to temperature – so the rate of diffusion and biodegradation will vary as a direct result of temperature.

1. Take a cube of jello from the container and place in a cup.
2. Fill the cup with warm water and watch the magic unfold!
3. You may want to try this with water that is colder and hotter to see the difference in diffusion and degradation rates. Be warned that the cooler the water, the longer diffusion will take.

VI. Other Applications

Scaffold for tissue engineering:

- Polymer scaffolds have various functions in the field of tissue engineering.
- They are often applied as space filling agents, as delivery vehicles for bioactive molecules, and as three-dimensional structures that organize cells and present stimuli to direct the formation of a desired tissue.
- Hydrogels are appealing scaffold materials because they are similar in structure to the extracellular matrix of many tissues, can often be processed under relatively mild conditions, and may be delivered in a minimally invasive manner.
- Polymers such as biodegradable and biocompatible amido-amine-based hydrogels are recently developed to be used as scaffold for tissue engineering because they are degradable in the body and are non-invasive and seldom cause adverse immune reactions.

Biosensors

- A biosensor is a device that detects the presence of any given substance or condition in the body.
- Biosensors can be made with hydrogels wherein the gel will expand or contract in response to the presence or absence of the specified substance or condition.
- Some examples are pH sensors, temperature sensors and glucose sensors to monitor glucose levels in diabetes patients.

Contact Lens

- The physical and chemical properties of hydrogel allow it to be an ideal material for contact lenses. Here are some of the characteristics:
    - Flexibility and ability to adapt to the global ocular curvature of the eye for optimal comfort
    - Permeability of oxygen, which is dissolved in the water and diffused to the cornea
    - High retention of water (70%-80%) to maintain moisture
    - Composed of biostable/biodegradable materials

Tissue Prosthesis:

- Because hydrogels have similar properties to many biological tissues, its applications extend to tissue regeneration and substitution.
- Study of and possible replacement of cartilage tissues: cartilage tissues also contain hydrophilic chains which retain water molecules which are then eliminated from the matrix when exposed to pressure.

Wound Gels

- Hydrogel sheets are used to protect wounds because they are excellent at creating and maintaining a moist environment.
- They help keep the wound clean by providing adsorption and removing necrotic or dead tissue.
- They also have a “soothing” effect which make them more acceptable to patients.
- Sometimes, these gels contain medication that they elute over a period of time.
- Specifically, they are used for management of pressure ulcers, skin tears, surgical wounds, and burns, including radiation therapy bums.
- Because they contain up to 95% water, hydrogels cannot absorb much exudate and are reserved for dry wounds or wounds with minimal to moderate drainage.

Soil Moisture

- Hydrogels contain a large amount of water, so they have multiple uses in agriculture.
- When seedlings are placed in rough environments, they have to compete with weeds and other plants for water and they often fail. To improve their success rate, they are coated onto hydrogels filled with water so that they will have a constant supply until they establish themselves.
- The usage of the hydrogels can help naturally poor soil to overcome its limitation on moisture retaining rate. Because hydrogels are able to retain a large amount of water, addition of hydrogels in soil largely increase the soil’s moisture level.

Water gel explosive :D

- A water gel explosive is an explosive mixture (slurry) consisting of a gelatinizing agent, a.k.a. a hydrogel, among other things. The consistency varies from easily pourable to hard solid.
- Polyvinyl alcohol, guar gum, dextran gums, urea-formaldehyde resins are the typical gelling agents.
- Water gel explosives are used because they are less toxic and cheaper and less hazardous than dynamite to manufacture and store.
- Water-gel explosives represent the majority of the blasting agents used in the commercial market and have almost completely displaced dynamite.

References

http://www.bioe.umd.edu/fischell-fellowship/janiak.html
http://csip.cornell.edu/curriculum_resources/CSIP/Neeves/KNeeves_teacherversion.pdf
http://www.iop.org/EJ/article/1742-6596/3/1/004/jpconf4_3_004.pdf?request-id=2994e7dc-c27b-48fe-9d23-859ad04e10f9
http://www.cheric.org/PDF/MMR/MR12/MR12-5-0507.pdf
http://en.wikipedia.org/wiki/Gel#Hydrogels
http://www.stevespanglerscience.com/experiment/helpful-hydrogels
http://www.sep.org.uk/catalyst/articles/catalyst_18_1_335.pdf
Encyclopedia of pharmaceutical technology, By James Swarbrick, James C. Boylan, Edition: 2, illustrated, Published by Informa Health Care, 2004