# Blank Activity Template

Yellow highlight = required component

**Subject Area(s)** AP Biology

**Associated Unit** Plants

**Associated Lesson** Biomimicry

**Activity Title** Plant-Like Power Plant

**Header**

| |
|---|
| **Image 1**<br>**Image file:** ___?<br>**ADA Description:** ___?<br>**Source/Rights:**<br>**Caption:** |

**Grade Level** __ ( 10 _ - _ 12 _)

**Activity Dependency**

**Time Required** 15 min

**Group Size** 3 – 4 students

**Expendable Cost per Group $0**

## Summary

Students will apply capillary action and hydroelectric energy equations to estimate the power output of a hydroelectric power plant based on the ability of trees to transport water hundreds of meters above ground.

## Engineering Connection

Micro- and nanochannels are becoming increasing researched as a way to cool/power small electronic devices. In conjunction with nanotechnology, biomimicry is developing as a useful method of product development.

## Engineering Category = #1

Choose the category that best describes this activity's amount/depth of engineering content:

1. Engineering analysis or partial design

## Keywords

Plants, capillary action, Chemical Engineering, Biology

## Educational Standards

***Science: Texas, science, 2009, The Texas Essential Knowledge and Skills, Chapter 112***

3D evaluate models according to their limitations in representing biological objects or events

## Pre-Requisite Knowledge

## Learning Objectives

After this activity, students should be able to:

- **Describe how water is transported through vascular plant systems**
- **Describe how scientists and engineers utilize biomimicry to solve human problems**
- **Use simple equations to predict desirable outcomes**

## Materials List

Each group needs:

- Calculators for each group member
- Optional: Coloring equipment and large piece of paper if groups want to illustrate power system

## Introduction / Motivation

In nature, trees are able to transport large amounts of water hundreds of feet above ground, against gravity, without the use of pumps or electricity. They are able to do all this passively by taking advantage of capillary action. Liquids, when introduced to a small space such as a microchannel or phloem tube, will "climb" through the tube as long as there is a force

## Vocabulary / Definitions

| Word | Definition |
|---|---|
| Biomimicry | The process of examining natural mechanisms to solve human problems. |
| Hydroelectric Energy | A form of energy generation where electricity is collected from moving water through a turbine, often using dams and/or gravity to provide the potential energy. |
| Capillary Action | The ability of a liquid to travel through a narrow space via surface tension and adhesive properties of the liquid and the surface. |
| Xylem/Phloem | The transport tissues in vascular plants that carry water and nutrients throughout the plant system. |

## Procedure

**Background**

This lesson is contained within the unit plant physiology, after the students have learned basic structures and functions of plants. Through the lesson, students are (re)introduced to capillary action and their use in both nature and nanotechnology. A common question is: "if trees can carry water up to impressive heights without using energy, can't we take the new potential energy and get 'free' energy?" Although this system appears simple, the mechanism to remove the water from the capillary tubes is far more complicated. Sunlight and atmospheric vapor pressure enables the evaporation of large amounts of water from the plants leaves, which have microstructures on the surface to aid this process. The evaporation at the top is basically what creates the "pump" that draws the water up the plants phloem, and this is the missing component of the energy budget and is why this system is not "free".

In this exercise, the evaporation process can be ignored so that the students can explore capillary action and hydroelectric energy mathematically. The equations to be used are provided in the PowerPoint file and are relatively straightforward. Briefly, the height that a liquid can climb in a tube is given by:

$$h = \frac{2\gamma \cos\theta}{\rho g r}$$

where h is height in meters, γ is the surface tension of the liquid (we used 0.0729 N/m for water), Θ is the angle of cohesion (we assumed 90° for simplicity), ρ is the density of the liquid (998 kg/$m^3$ for water), g is the acceleration due to gravity, and r is the radius of the channel (kept in meters but students should be designing tubes that are micro- and nanoscale).

The energy produced by a hydroelectric generator can be predicted using:

$$P = \rho h r g k$$

where P is the potential energy of the water going through the turbine, ρ is still the density of the liquid, h is the height of the liquid before it flows to the generator, r is the flow rate in $m^3$/s (this is controlled by the flow coming up the microchannels, use 3404 g/$m^2$ s), g is acceleration due to gravity, and k is the efficiency factor (we've used a hypothetical 80% efficiency so k=0.8).

Really the only variables the students need to adjust are the radius of the microchannels and the number of microchannels. This gives the height dimension and potential energy acquired by the generator.

**Before the Activity**

- Review capillary action and hydroelectric power generation
- If the students do not already have groups, separate them into groups of 3-4 students and place them at their lab stations

**With the Students**

1. Students will use the equations provided in the lesson to design a power plant with comparable energy output to a real-life power plant (e.g. 700 megawatt coal-fired power plant).
2. After students have worked through the equations, have them report to the rest of the class what size tubes they used, how high the water was transported, how many tubes were required, and how large the power plant has to be.

Image

**Figure 1**

**ADA Description:** ___?

**Source/Rights:** Taken by Self

**Caption:** Figure 1: Distillation Setup

Note: If activity is accepted, will submit pictures of the setup used in classroom

## Attachments

Biomimicry Lesson
Perpetual Energy PowerPoint Presentation
The Essence of Herbs Pre-Lab Quiz

## Safety Issues

## Troubleshooting Tips

## Investigating Questions

## Assessment

**Pre-Activity Assessment**
*Descriptive Title:* ___?

**Activity Embedded Assessment**
*Descriptive Title:* ___?

**Post-Activity Assessment**
*Descriptive Title:* Biomimicry Quiz

## Activity Extensions

## Activity Scaling

- For lower grades, ___?
- For upper grades, ___?

## Additional Multimedia Support

## References

## Other

## Redirect URL

## Contributors

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## Supporting Program

National Science Foundation GK-12 program, University of Houston, Department of Civil and Environmental Engineering

## Classroom Testing Information

**This activity was demonstrated at North Shore Senior High School, Houston TX, on March 28th 2012.**