Biological Currency

Introduction

Money is an interesting item for people and thus serves as motivation for microscopic observation and measurement. Microscopic and chemical analysis of money leads to a new scientific view of money.

Concepts

- Field of view
- Iodine–starch test
- Properties of starch
- Microscopic magnification

Background

Counterfeiting money is not a new high-tech crime. It has been occurring ever since the introduction of paper money. During times of war countries often printed counterfeit money of their rivals to destroy the enemy's economy. After the Civil War an estimated one-third of all paper money in the United States was counterfeit. On July 5, 1865, the Secret Service was created within the Department of the Treasury with the sole mission of suppressing counterfeit currency. Unfortunately, counterfeiting is still prevalent. The advent of desktop computers, scanners, laser color printers, and other precision high-tech equipment has emboldened more people to try counterfeiting currency, even though the penalty for possessing or creating counterfeit money is 15 years in federal prison.

A second division of the Department of the Treasury, the Bureau of Engraving and Printing (BEP), is in a continual race in an attempt to keep ahead of the counterfeiters. The appearance of U.S. paper currency had not changed much in the period from 1928 until 1996, when the BEP began making significant changes. Since 1996, the BEP has changed the one-dollar bill once and the larger denominations twice in an effort to inhibit the ability of counterfeiters to make fake money. New security features on paper currency include a watermark, a security thread that is only visible when the paper currency is held up to light, color-shifting ink, subtle background color changes across the bill, changes to the portraits, fine-line printing patterns, and microprinting that is only visible with a microscope.

Even the art of papermaking has advanced at a rapid rate in recent years. U.S. currency paper is different than regular paper. Currency paper is a special blend of linen and cotton cellulose, not wood cellulose like regular paper. Currency paper is finished differently than regular paper during the "sizing" process. Ordinary paper is sized with starch to fill the gaps between the cellulose fibers and stiffen the paper, much like starch on a shirt collar. Starch also makes the paper less absorbent and improves its ability to be written upon. In the production of U.S. currency, starch is not used, thus, U.S. currency will give a negative test result (i.e., no color change) when tested with iodine. Many counterfeit detection pens used commercially contain an iodine–iodide reagent for the starch test.

Starch and cellulose are both polymers of glucose. Starch is made of a long chain of β-D-glucose molecules while cellulose molecules are chains of β-D-glucose (see Figure 1).

The seemingly minor differences in the shape of the building block molecules make very differently shaped polymers. Cellulose molecules are long and straight like spaghetti. Like spaghetti, cellulose molecules tend to attract each other and form long, rigid bundles. Starch molecules in contrast are coiled molecules much like a spring. This rigid iodine–iodide (I_2/KI) test reagent reacts differently with these two differently shaped polymers. Iodine doesn't penetrate the cellulose fibers and the net result is no reaction (no color change). Loosely held electrons on iodine atoms attract atoms on the inside of the starch molecule and form strong bonds that change the way the light is absorbed by the polymer. The result of this reaction between starch and iodine is the dark blue color associated with a positive starch test.

Materials

Compound microscope with optional ocular micrometer
Iodine–potassium iodide solution or Lugol's solution
One-dollar bill after 1996
Paper, white
Petri dish
Pipet, disposable
Ruler, metric, clear
Slice of apple
Slice of potato
Stereo microscope

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Safety Precautions

Iodine–potassium iodide solution may be a skin irritant. It will also form its characteristic dark-stained complex with anything containing starch, including all paper, books, and some clothing. Avoid all contact with skin, clothing, and lab materials. Wash hands thoroughly with soap and water before leaving the laboratory. Wear chemical splash goggles when working with any laboratory chemicals. Please consult current Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

Part I. Big Money

1. Use a stereoscope to examine a one-dollar bill. Use only the top (incidental) light to study the bill.
2. Continue to examine the one-dollar bill using only the bottom (transmitted) light. How does the appearance of the one-dollar bill change when the light is switched from incidental light to transmitted light?
3. Answer questions 1–5 in Part IA on the Biological Currency Worksheet.
4. Place a clear metric ruler on top of the one-dollar bill and view both under the stereoscope. The circular light area seen when looking through the eyepiece is called the field of view. Use the ruler to measure the field of view. (Measure the diameter from one edge of the field of view to the opposite edge.) Estimate to the nearest 0.1 mm. Record the measurement and microscope power in question 6 on Part IA of the Biological Currency Worksheet.
5. Use a compound microscope to look at the one-dollar bill. Use 100X magnification and adjust the amount of light carefully when focusing the microscope. Answer question 1 on Part IB of the Biological Currency Worksheet.
6. Use the ruler to measure the diameter of the field of view at 100X magnification. The distance from the center of one line to the center of the next is 1 millimeter (1000 microns). Use the center of one line as shown in Figure 2 to estimate the field of view. Estimate the diameter to the nearest 0.1 mm. Record the measurement in question 2 and answer questions 3–4 in Part IB on the Biological Currency Worksheet.
7. If the ocular of the microscope contains a micrometer, measure the field of view at 100X and compare it to your measured value from step 6.

Part II. Counterfeit

1. Obtain a small slice of potato and a small slice of apple in a Petri dish.
2. Use a pipet to place one drop of iodine–potassium iodide solution on both the potato and the apple slice. (A dark blue/purple color indicates the presence of starch.)
3. Record observations and the test results in Part IIA on the Biological Currency Worksheet.
4. Use a pipet to place a drop of the iodine–iodide test solution on piece of white paper and another drop on the one-dollar bill. Record the results in Part IIA on the Biological Currency Worksheet.
5. Answer questions 1–3 for Part IIB on the Biological Currency Worksheet.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. Dispose of all items in the trash according to Flinn Suggested Disposal Method #26a. Please consult your *Flinn Scientific Catalog/Reference Manual* for proper disposal procedures.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-PS1 Mater and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions
MS-LS1 From Molecules to Organisms: Structures and Processes
LS1.A: Structure and Function

Disciplinary Core Ideas: High School
HS-PS1 Mater and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions

Science and Engineering Practices
Planning and carrying out investigations
Analyzing and interpreting data

Crosscutting Concepts
Patterns
Structure and function

Tips

- Provide other interesting items for microscopic examination and measurement practice.
- The Bureau of Engraving and Printing provides free teacher materials through their Web site, www.moneyfactory.gov (accessed August 2016).
- The Secret Service provides anti-counterfeiting information on their Web site, www.secretservice.gov investigation/#counterfeit (accessed August 2016).

Answers to Post-Lab Questions

Part I. Big Money

A. Stereomicroscope

1. How many arrows is the eagle holding? *13*
2. How many stars are above the eagle? *13*
3. How many stars are above the key? *13*
4. What is the number on the bottom of the pyramid? *1776 (MDCCLXXVI)*
5. What color fibers make up the currency paper? *Red*, *white*, *blue*
6. Field of view:
   a. Magnification _____
   b. Field of view (0.1 mm) _____

B. Compound Microscope

1. Describe in detail two things seen with 100X magnification that were not visible using the stereoscope. Sketch them.

   Dots and dashes compose the lines that make up the web feature and facial features of President Washington. (This is called microprinting.)

2. Fields of view:
   i) Magnification _____
   ii) Field of view _____ (0.1 mm) _____ (μm)
3. What happens to the field of view as the magnification increases?

   It becomes proportionally smaller.

4. Assuming that the field of view is inversely proportional to the magnification, calculate the field of view for 400X magnification based on the field of view for 100X magnification in Part IB, question 2.

   375 μm

Part II. Counterfeit

A. Iodine/Starch Test Results

Item	+ or –
Potato	+
Apple	–
One-dollar paper	–
White paper	+

B. Questions

1. What do potatoes and paper have in common?

   Both contain starch (α-D-glucose polymer) and therefore test positive using the iodine–iodide mixture.

2. Design a simple device to detect counterfeit money printed on regular paper.

   An iodine stamp or pen would stain paper and not currency paper.

3. How can a microscope be used to detect counterfeit money?

   The type and texture of the paper and microprinting can be seen using a microscope.

Reference

M. McClure; Chemical Counterfeit Catcher, Chem Matters; October, 1997.

Materials for *Biological Currency* are available from Flinn Scientific, Inc.

Catalog No.	Description
I0038	Iodine–Potassium Iodide Solution, 100 mL
AP5387	Metric/English Ruler, 6-in, Clear
MS1131	Flinn Stereoscope, Economy
MS1121	Flinn Economy Compound Microscope
MS1160	Flinn Stereoscope, Standard
MS1176	Eyepiece with Reticle

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Name: _____

Biological Currency Worksheet

Part I. Big Money

A. Stereomicroscope

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2. How many stars are above the eagle?
3. How many stars are above the key?
4. What is the number on the bottom of the pyramid?
5. What color fibers make up the currency paper?
6. Field of view:
   a. Magnification _____
   b. Field of view _____

B. Compound Microscope

1. Describe in detail two things seen with 100X magnification that were not visible using the stereoscope. Sketch them.

2. Fields of view:
   a. Magnification _____
   b. Field of view _____ (0.1 mm) _____ (microns)
3. What happens to the field of view as the magnification increases?

4. Assuming that the field of view is inversely proportional to the magnification, calculate the field of view for 400X magnification based on the field of view for 100X magnification in Part IB, question 2.

Part II. Counterfeit

A. Iodine/Starch Test Results

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