Teacher's Preparatory Guide

Using Gold Nanoparticles for Bacterial Detection

Overview: In this lab students will become familiar with gold nanoparticles, or GNPs. As part of the lesson students will learn the potential disease detection uses of GNPs, conduct research on modifying GNPs to be specific to other molecules, and complete a simulation using GNP assay tests to detect a simulated meningitis (*Neisseria meningitides)* outbreak in the class.

Purpose: This lab is designed to introduce students to gold nanoparticles and some of their applications. Students will create GNPs in the lab and use their resulting product in a simulated assay test to detect 'meningitis antigens' among their peers. Real nanoparticle-based assay tests use GNPs coated with appropriate receptors that react to specific molecules for detection. This particle coating process is quite complex and impractical for the classroom, so the 'assay test' portion of the activity will be a simulation where the antigen will be played by NaCl.

As an extension to this activity students can research methods of treating GNPs to be molecule specific to antigens. Results can be shared with the class.

Time Required. Three to five 50 min periods

Level. High school Biology or Chemistry; grades 9-12

Teacher Background
Gold nanoparticles (GNPs) have been used for hundreds of years. Historically the uses of GNPs have ranged from dyes in ceramics and art to 'cure all' tonics ingested for gold's supposed curative properties. You may want to read *Introduction to Metallic Nanoparticles*[1] for more background information.

Recently, because of technological advances, the numerous uses of GNPs have opened up into a new and exciting field. Nanoscience has become a vast area of research ranging from material sciences and textiles to health care and the biomedical field. Materials with nanoscale structures, such as nanoparticles, dendrimers, nanopores, and quantum dots have opened new worlds of possibilities. The instructor may want to take the class through *Understanding Nanodevices*[2] to show examples of nanotechnology in the medical field.

One promising area of applied nanotechnology is that of gold nanoparticles, small clusters of gold atoms between 10nm and about 500nm in size. Research and development on the uses of GNPs has shown great progress. One such application uses GNPs that specifically bind to certain molecules by the use of bonding ligands, short molecules that are stuck on the surface of the nanoparticle and are designed to attach to a specific target molecule. This ability enables GNPs to target a wide variety of biological materials, including viruses, bacteria, proteins, cellular components, and tissue. Other uses of GNPs range from early detection of disease, via bio assays

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and other diagnostic tests, to the delivery of specific drugs and the destruction of tumors. The instructor may want to show a short video on these subjects and read through *Video Journey into Nanotechnology*[3].

Companies such as *BioAssay Works* have already engineered a GNP assay test that can be custom ordered to detect a large number of molecules cheaply. Teachers may want to read the *BioAssay Works*[4] website for more information.

Part II of this lab introduces bacterial meningitis caused by *Neisseria meningitidis* bacteria. This disease is contagious through bodily fluids and outbreaks commonly affect areas with young populations, such as colleges. The teacher may want to review the *Meningococcal Disease*[5] website presented by the Centers for Disease Control (CDC). Students will simulate an outbreak in class by simulated "kissing" (i.e., swapping test tube fluids).

Sources

1. J. Pharm. Bioallied. Sci., "Introduction to metallic nanoparticles" (July, 2013) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2996072/
2. National Cancer Institute. Nano devices (July, 2013) http://www.cancer.gov/cancertopics/understandingcancer/nanodevices.
3. National Cancer Institute. "Video Journey into Nanotechnology (July, 2013) http://nano.cancer.gov/learn/understanding/video_journey.asp
4. BioAssay Works. "Ultra-sensitive gold technologies" (July, 2013) http://www.bioassayworks.com/
5. Center for Disease Control and Prevention. "Meningococcal Diseases" http://www.cdc.gov/meningococcal/about/symptoms.html

Advance Preparation:

Materials and Equipment

Teacher Notes: Advance Preparation

Prepare the solutions according the following directions (below). The amounts given will prepare enough solution for 8 lab groups. Increase or decrease the amounts to suit your needs.

Part I- Making solution for use in gold nano particles gerneration

- 0.1 g $HAuCl_4$- chloroauric acid
- 0.5 g $Na_3C_6H_5O_7$-sodium citrate
- 250mL and 50mL distilled H_2O
- Stir rod
- 50ml Erlenmeyer flasks
- 250ml Erlenmeyer flasks
- 8 vials or test tubes (minimum size is 20mL)

Part II – Making NaCl solution for GNP Assay Test Simulation (students work in 2-3 lab groups of ~12 students)

- 0.5 g NaCl-table salt
- vials or test tubes (one per group)
- 10mL Distilled water
  - 1 test tube with NaCl solution (simulated antigen, given to one student)
- You will also need vials of distilled H_2O for the other members of the group

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- Label the vials so you know which one is the vector (NaCl solution)

Source/Website	Material
Sigma Aldrich (http://www.sigmaaldrich.com)	• $HAuCl_4$- Chloroauric acid • Sodium citrate
Carolina or other science supply vendor (http:// www.carolina.com)	• 50 ml Erlenmeyer Flask • 100 ml Erlenmeyer Flask • 10ml Test Tubes • 20 ml beaker • 500 ml beaker • Eye droppers • Hot Plate
Grocery Store	• Sodium Chloride • Distilled Water

Part III- Researching GNPs

- Access to computers with Internet

Directions for making the solutions for Part I and Part II

Part I- Producing GNPs.

1. Prepare 250 ml of 1.0 mM $HAuCl_4$ solution by dissolving 0.1 g of $HAuCl_4$ in 250 ml of distilled water. Equally distribute this solution into 8 vials that are large enough to hold 20 ml of solution. This solution is unstable and keeps only a few days, so make it fresh for the lab.
2. Prepare 50 ml of 38.8 mM sodium citrate solution by dissolving 0.5 g of $Na_3C_6H_5O_7$ in 50 ml of distilled water.

Part II- Assay Test Simulation

1. Prepare a 1 M solution of NaCl by dissolving 0.5 g of NaCl in 10 ml of distilled water to be used as antigen. (Each part II group needs one sample of this to act as a meningitis vector for the simulation)

Safety Information:

Goggles and gloves should be worn during the gold nanoparticle synthesis reaction. Proper waste disposal should be used per school's procedures.

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Suggested Instructional Procedure:

Time	Activity	Goal
Day 1	**The day before the lab**	
50 min	Introduce students to the topic of nanoparticles. Discuss gold nanoparticles specifically. Have students research uses, and share with class. This lab is intended to connect GNPs to the medical field. The lab simulates a meningitis assay test. Feel free to change the disease to whatever fits your curriculum. Review how assay tests are used. Prepare lab material for part I and II.	To prepare students to create and use gold nanoparticles for medical uses as an assay test.
Day 2	**The day of the student lab part I**	
5 min	Students answer warm-up questions. "what are gold nanoparticles?" "discuss three uses for gold nanoparticles with your partners."	To ensure students understand what gold nanoparticles are and how they can be used…specifically as assay tests.
35-40 min	Distribute *Student Worksheets* to students. Students follow procedures and complete Part I of the lab. Any extra time could be spent reviewing assay tests.	To allow students to complete part I of the lab.
5min	Clean up.	To prepare workspace for next class.
Day 3	**The day of the student lab part II**	
5 min	Students answer warm-up questions. "what are gold nanoparticles?" "Why is part II of this lab only a simulation" "What should we notice in our samples when the GNP is added?"	To ensure students understand what gold nanoparticles are and how they can be used…specifically as assay tests.
35-40min	Instruct student to take out Student Worksheets. Students follow procedures and complete Part II of the lab	To allow students to apply their GNPs to solve a problem. "Who has meningitis and who started the outbreak?"
5min	Clean up.	To prepare workspace for next class.
Day 4 (optional)	**The day of the student lab part III**	

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5 min	Students answer warm-up questions. "what are gold nanoparticles?" "How did GNP allow us to detect infected people yesterday?" "How was yesterday's lab realistic and unrealistic?"	To ensure students understand what gold nanoparticles are and how they can be used…specifically as assay tests.
35-40min	Instruct student to take out Student Worksheets. Students follow procedures and complete Part III of the lab	To allow students to apply their GNPs to solve a problem. "How can GNPs be modified to be used for nanoscience?"
5min	Clean up.	To prepare workspace for next class.
Day 5 (optional)	**The day of the student lab part III**	
45 min	Students present findings from previous day's research.	

Teaching Strategies. Part I of the lab (creating GNPs) can be completed in groups of 4-5. Circulate as students work to answer questions and monitor safety.

Part II of the lab can be completed as follows. Have 2-3 groups work together for this part (10-15 students... you may have to break groups up from part I). Each student will have a test tube filled with distilled water, except for the meningitis vector who will have a NaCl solution.

Students will then begin to "kiss", that is, they simulate the swapping of body fluids represented by the test tube liquid. To do this a pair of students will exchange 2 ml of test tube liquids using the eye droppers. Have each student "kiss" two people from their group. Be sure students don't kiss too much or everybody will become infected!

Guided Dialog *Before* beginning the lab, review the meaning of these terms:

Nanotechnology-. *Technology applied to the nanoscale, usually defined as under 100nm.*

Gold Nanoparticle (GNP)- *Particles of gold ranging in size from 10 to –a few hundred nm in size. Current research suggests a multitude of uses for these particles including early detection and treatment of several diseases.*

Assay Test- *An assay test is a quantitative in vitro test for a molecule such as an antibody or antigen in which the test material is absorbed on a surface and exposed either to a complex of an enzyme linked to an antibody specific for the antigen. Upon GNPs bonding with target molecule a color change will occur.*

Antigen- *A foreign molecule that does not belong to the host organism and causes an immune response.*

Neisseria meningitidis bacteria-The bacterium responsible for bacterial meningitis. This disease is contracted through body fluids and is very contagious. Symptoms include- headache, fever, vomiting, confusion, and sensitivity to light. Severe cases may result in hearing loss or death.

Ask students questions to provoke thought and review what they already know:

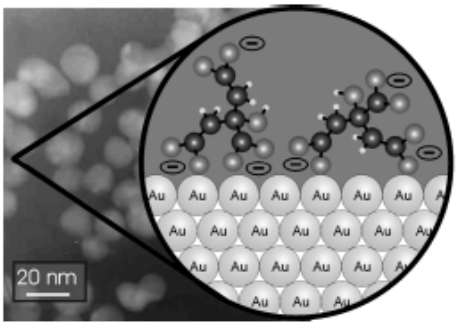
1. What are gold nanoparticles? How big are they? *GNPs are particles of gold that range in size between 10 and a few hundred nm and can be modified to target specific molecules. An example of a target could be antigen of the Neisseria meningitides bacterium which causes meningitis.*
2. What is an assay test? *An assay test is a quantitative in vitro test for molecules such as an antibody or antigen in which the test material is absorbed on a surface and exposed either to a complex of an enzyme linked to an antibody specific for the antigen. Upon GNPs bonding with target molecule a color change will occur.*
3. What is bacterial meningitis, how is it transmitted, and how is it detected? The bacterium responsible for bacterial meningitis. The disease is contracted through body fluids and is very contagious. Symptoms include- headache, fever, vomiting, confusion, sensitivity to light, hearing loss, death.
   It's transmitted through bodily fluids.
   Cerebral spinal fluid (CSF) can be tested by a variety of means for bacterial meningitis antigen (one method is an ELISA (Enzyme Linked ImmunoSorbant Assay) Test). We will be simulating a gold nanoparticle assay test.

Part I materials per group of students:
Vial with 20mL of 1.0 mM HAuCl4 solution
Vial of 38.8 mM $Na_3C_6H_5O_7$ solution (citrate solution)
50mL Erlenmeyer flask
Hot plater/stirrer
Magnetic stir rod
10mL graduated cylinder
Test tube or screw top vial
Permanent maker or grease pencil

Procedure:

Part I. Students will:

1. Obtain a vial of 1.0 mM HAuCl4 solution. This vial should contain ~ 20 ml of solution.
2. Pour the contents of this vial into a 50 ml Erlenmeyer flask.
3. Place the Erlenmeyer flask on a hot plate and heat to boiling. Stir while the solution is heating.
4. Obtain a vial of 38.8 mM sodium citrate ($Na_3C_6H_5O_7$) solution and use a 10 ml graduated cylinder to measure out 2 ml of the 38.8 mM citrate solution.
5. After the HAuCl4 solution begins to boil, add the 2 ml of citrate solution.
6. Continue to boil and stir the solution until a deep red color appears. This takes about 10 minutes.
7. Turn off the hot plate and allow the solution to cool to room temperature.
8. Students label a test tube or screw-top vial with their names and pour the nanoparticles into their labeled vial.



Left: A micrograph of 13 nm-diameter Au nanoparticles. Right: An illustration an Au nanoparticle surface. Each nanoparticle is made of many (more than 500,000) Au atoms. Citrate anions cover the nanoparticle surface.

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9. Labeled vials of gold nanoparticles are stored by the teacher to complete part II of the lab the next day.

Part II. Materials for each group of ~12 students

- Pipet or eye dropper (preferably graduated)
- Test tube or vial filled with 10mL of distilled H_2O – one per student in each group
- Test tube or vial filled with NaCl solution – one student in each group receives this (vector should not be known to the group).
- Test tube or vial of GNP solution students prepared during day one

Part II.

1. Separate students into groups of 10-15 (you may just want to combine 2-3 groups from part I)
2. Give each student an eye dropper and at a test tube filled with 10 ml of distilled water EXCEPT for one student who you select to receive the meningitis sample (NaCl solution)
3. Instruct students to "kiss" two other people (as meningitis is contagious via body fluids). To "kiss" students will squirt 2ml of their test tube solution into a partner's test tube and vice versa. Be sure students don't touch other test tubes or submerge in other test tubes to avoid contamination.
4. After students have kissed the assigned number of students, have them return to their lab table.
5. Students will add 1.5 ml of their GNP from day 1 to mimic an assay test.
6. A color change will signal a positive result for meningitis (positive results should change blue). No color change or a slight brightening of the pink red signals a negative result for meningitis.
7. *Optional:* have students return to their "kissing" groups. Students can play the part of an epidemiologist by figuring out who was the original vector of the disease. (NOTE- if you choose to complete this optional part it is necessary to write down which students receive the NaCl solutions, as they are the vectors).

Cleanup:

Instruct students to return all chemicals to the teacher for proper disposal or direct them to dispose per teacher instructions.

Part III (optional)

1. Assign students to groups of 3-5.
2. Students research real world methods of modifying GNPs for use in the medical field.
3. Students create 2-3 min PowerPoint presentation to share info.

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Enhancing Understanding:
Have students present a review of their findings with the class via a short presentation Students should be able to answer the questions below:

What was the purpose of part I of the lab:
Part I's purpose was to create gold nanoparticles. Unfortunately we are unable to modify the surface of the GNP's in the classroom to make them specific to an antigen so we created GNP's with a coating of citrate that would react with NaCl.
Part II simulated students exchanging bodily fluids and possibly meningitis. What was the purpose of adding GNP?
GNP was added to the sample during part II to simulate an assay test. If this were a real assay test the GNP's surface would have been modified to be specifically attach to the bacterial meningitis antigen thus reacting with and only with the antigen.
Optional- What are some examples presented in part III of how GNP's can be modified to be used in the medical field. Examples will vary

Going Further: Students who have a good grasp of the content of the lab can be further challenged with these questions:

1. In your part I groups, research one way in which GNP surfaces can be modified to be specific to a molecule (ex specific strain of DNA, RNA or protein) Present your findings to the class with a slide presentation (using Power Point or equivalent). *Answers will vary*

Assessment:
Assessing this lab can be done in a variety of ways. Partial credit for part I, part II, part III, conclusion questions, and presentations. NOTE: If students fail to create GNPs during part I you may want to have premade samples ready to be used in part II. A rubric is attached for the optional PowerPoint presentation.

Resources: You may wish to use these resources either as background or as a resource for students to use in their inquiry-based design.

- J Pharm Bioallied Sci. "Introduction to metallic nanoparticles" (July, 2013) http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2996072/
- National Cancer Institute. "Video Journey into Nanotechnology (July, 2013) http://nano.cancer.gov/learn/understanding/video_journey.asp
- National Cancer Institute. Nano devices (July, 2013) http://www.cancer.gov/cancertopics/understandingcancer/nanodevices.
- BioAssay Works. "Ultra-sensitive gold technologies" (July, 2013) http://www.bioassayworks.com/
- Center for Disease Control and Prevention. "Meningococcal Diseases" http://www.cdc.gov/meningococcal/about/symptoms.html

National Science Education Standards (grades 9-12)

- Content Standard A
  - Abilities necessary to do scientific inquiry
  - Understandings about scientific inquiry
- Content Standard B
  - Structure of atoms

    - Chemical reactions
- Content Standard E
    - Abilities of technological design

Next Generation Science Standards

- HS-PS1.B Chemical Reactions
- HS-ETS1.C Optimizing the Design Solution
- HS-LS1-2 Develop and Using Models

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Name:_____Date:_____Class:_____

Student Worksheet

Using Gold Nanoparticles for Bacterial Detection

Safety

Always wear appropriate safety gear when using chemicals, including safety goggles, plastic gloves, and if needed, aprons. Never dump chemicals down the sink unless told to do so by an instructor. Dispose of chemicals appropriately.

Introduction

How do scientists and doctors test for diseases? How do they use nanotechnology to assist in early detection of diseases…especially contagious diseases like bacterial meningitis (*Neisseria meningitides)?* Over the next few days you will learn about applications of gold in nanotechnology, create gold nanoparticles (GNPs) to be used to detect a disease (GNP assay test), and simulate an assay test for meningitis. A real meningitis test would involve a spinal tap to test samples of one's cerebral spinal fluid (CSF), a painful procedure! Instead, the second part of this lab will be done as a simulation, due to the fact that modifying GNPs in the classroom to be able to test for a specific antigen is beyond the scope of this class…and using real meningitis would lead to a lawsuit!

During part I of this lab you will be creating gold nanoparticles (GNPs) approximately 15 nm in size (that's small!). The particles will be covered in a citrate layer that will prevent the gold particles from 'bumping' into each other, sticking and therefore making larger and larger particles. The nanoparticle surfaces can be modified to attach to just about any molecule or antigen. These GNPs will be used to detect simulated meningitis bacteria which will "infect" some of your classmates.

Part II of this lab will consist of all students "kissing" two other students (bacterial meningitis is only contagious through bodily fluids)! Ok, settle down, you won't actually kiss…we will simulate swapping spit by using test tubes and eye droppers. We will then use our engineered GNPs to detect those of you who have contracted the disease.

Optional: For those interested in the work of an epidemiologist, try looking at the results and determine who was the original carrier/vector of the disease.

Part III of this lab will enable groups to research ways in which GNPs are being used in the medical field and share the info to the class via PowerPoint.

Prelab- Read the following and answer the questions below.

1. Introduction to Metallic Nanoparticles - *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2996072/*

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2. BioAssay Works - *http://www.bioassayworks.com/*

3. Meningococcal Disease - *http://www.cdc.gov/meningococcal/about/symptoms.html*

1. What are metallic nanoparticles and list 2 ways in which the medical field uses them. Metallic nanoparticles are particles of metal materials on the order of 10 to a few hundred nanometers (not greater than 700). They have high surface area to volume ratios and if they are stable and biocompatible they may have important applications in biotechnology and nano-medicine. Two possible uses are imaging probes and directed drug delivery. They can also be used for disease detection.

2. Why are gold nanoparticles used in the nano field? What properties make them a great candidate for nanotechnology? Gold nanoparticles are typically made in the range of 10-20nm but can be larger (30-100nm). As with other nanoparticles they have high surface area to volume ratios which allows for a large surface to utilize. They have unique optical properties and their surface allows certain materials to adhere – particularly ligands. These properties make them useful in imaging and in drug delivery and treatment.

3. What is Bacterial Meningitis? This is a bacterial infection that causes a swelling of the membranes that protect the brain and spinal column. The disease is spread by direct contact to secretions from the throat and lungs (saliva and mucus). The bacteria are not spread by casual contact such as breathing the air of a person with meningitis.

4. What are 4 symptoms of bacterial meningitis and how is it passed from person to person? Symptoms include sudden onset of fever, headache, and stiff neck. These symptoms area accompanied by nausea, vomiting, sensitivity to light, and confusion. Transmission is through direct contact with spit from an infected person.

Materials

Part I- Making Gold nano particles

- $HAuCl_4$- Chloroauric acid
- $Na_3C_6H_5O_7$-Sodium citrate
- 50 ml Erlenmeyer Flasks
- Test tubes or screw top vials
- Eye droppers/pipets (graduated if possible)
- Hot plate/stirrers
- Stir bars
- 10mL graduated cylinder
- Marker/grease pencil

Part II Meningitis outbreak!

- Test tubes with simulated CSF fluid
- Eye Droppers
- GNP's from Part 1

Question: How can gold nanoparticles be used to detect the presence of bacterial meningitis?

Make a Prediction

Answers will vary but should include something about a response to detecting the bacteria.

Part I Procedure- Making Gold Nanoparticles

1. Obtain a vial of 1.0 mM HAuCl4 solution from your teacher. This vial contains ~ 20 ml of solution.
2. Pour the contents of this vial into a 50 ml Erlenmeyer flask.
3. Place the Erlenmeyer flask on a hot place and heat to boiling. Stir while the solution is heating.

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4. Obtain a vial of 38.8 nM $Na_3C_6H_5O_7$ solution from your teacher and use a 10 ml graduated cylinder to measure out 2 ml of the 38.8 mM $Na_3C_6H_5O_7$ solution.
5. After the $HAuCl_4$ solution begins to boil, add the 2 ml of $Na_3C_6H_5O_7$ solution.
6. Continue to boil and stir the solution until a deep red color appears. This takes about 10 minutes.
7. Turn off the hot plate and allow the solution to cool to room temperature.
8. Label your vial with your names and pour the nanoparticles into your labeled vial.
9. Bring your vial of gold nanoparticles to the teacher to store for use in Part II.

Part II- Meningitis outbreak!

Today you will be working in a group of about a dozen people to be determined by your teacher. Each member of the group will receive a test tube filled with a clear liquid that is your simulated bodily fluid. One sample is a carrier of simulated meningitis. Your job is to determine who has the disease after all the "kissing" is done by analyzing the simulated cerebral spinal fluid (CSF) samples.

Optional: For an added challenge play the part of epidemiologists as a group and see if you can decided who originally had the disease. To do this, each one of your will need to record who you have exchanged fluids with, and in what order. You can then create a flow chart of the group members to illustrate who was infected and who was the original carrier. At the end of the simulation, those who test positive for the simulated meningitis can compare notes and trace the disease back to its source.

Procedure:

1. Your teacher will break the class into groups of 10-15 people. Don't worry if you are not with your part I groups.

2. Get an eye dropper and a test tube filled with bodily fluids from your teacher. (Don't worry--it's not really bodily fluids, just water. Still, do not drink it!).

3. When your teacher tells you to begin, you will "kiss" another person in your group.

NOTE- No need to really kiss! Instead, squirt 2ml of bodily fluid from your test tube into a partners test tube being careful not to touch the other test tube or fluid (don't contaminate your eye dropper). At the same time you partner will squirt 2ml of bodily fluid into yours. Mix your test tube afterwards with your eye dropper.

4. Complete step 3 one more time with a second person in your group.

5. You will now use your GNPs from part I to detect if you have contracted bacterial meningitis.

6. Because everybody has possibly been "exposed", you must all unfortunately receive a spinal tap…ouch! Your test tubes now represent cerebral spinal fluid (CSF).

7. Add 1.5ml of GNP specific to bacterial meningitis antigen to your CSF. Stir sample using a stir stick or dropper.

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8. A color change will signal a positive result for meningitis (positive results should change to blue). No color change or a slight brightening of the pink red signals a negative result for meningitis.

Record Your Observations:

Patient Name(group member)	Test result	Patient Name(group member)	Test result

Part III - How are GNPs used in the medical field?

1. In your assigned group, research and create a 2-3 min presentation to share with the class discussing one specific example of how GNPs are used in the medical field. Be sure to give specific examples of GNP creation, surface modification, uses, side effects, and outlook.

Draw Conclusions:

1. Why was it important to treat the gold particles with citrate? How would your results have been different if we hadn't used citrate?

   Answers will vary but should indicate that citrate created a surface that prevented gold particles from sticking together.

2. Why did we have to run a simulation with a meningitis assay test using GNPs ?

   In order to actually create the assay test we would have to modify the surface of the GNP to be specific to the antigen in question. Obviously Bacterial Meningitis would be dangerous to handle in class.

3. How many people were in your group? How many people tested positive? Explain why a negative test doesn't necessarily clear an individual from having the disease. What limitations do assay tests have?

   Answers vary. A limitation could include the nanoparticles not reaching the targeted material due to small amounts of either the GNPs or the bacteria.

4. In your Part I group, research a method of modifying the surface of GNPs to be specific to an antigen, virus, RNA or DNA etc. Give a short PowerPoint presentation to share your findings with the class.

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Rubric for evaluation of PowerPoint of GNP assay method

Category	Exemplary 4	Accomplished 3	Developing 2	Beginning 1	Points
Content	Includes in-depth details and examples. Subject knowledge is excellent. Clearly explains method chosen.	Includes essential knowledge about the topic. Subject knowledge appears to be good. Adequately explains method chosen.	Includes essential information about the topic but there are 1-2 factual errors. Does not fully explain the method chosen.	Content is minimal or there are several factual errors. Does not explain the method chosen.	
Illustrations	Uses well labeled illustrations to describe method and application.	Uses illustrations to describe method but lacks details of method and application.	Poorly illustrated images used to describe method and application.	No images used to explain method and application.	
Examples	Provides clear and understandable example(s) of how the method is used and the connection to nanotechnology.	Provides good example(s) of how the method is used and the connection to nanotechnology.	Provides poorly defined example(s) of how the method is used and the connection to nanotechnology.	Does not provide example(s) of how the method is used nor the connection to nanotechnology.	
Organization	Content is well organized using headings or bulleted lists to group related material.	Uses headings or bulleted lists to organize, but the overall organization of topics appears flawed.	Content is logically organized for the most part.	There was no clear or logical organizational structure, just lots of facts.	
Sources	Provides a detailed list of sources used in developing the PowerPoint.	Provides a list of sources used in developing the PowerPoint.	A limited source list used to develop the PowerPoint is provided.	No source materials are provided.	

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