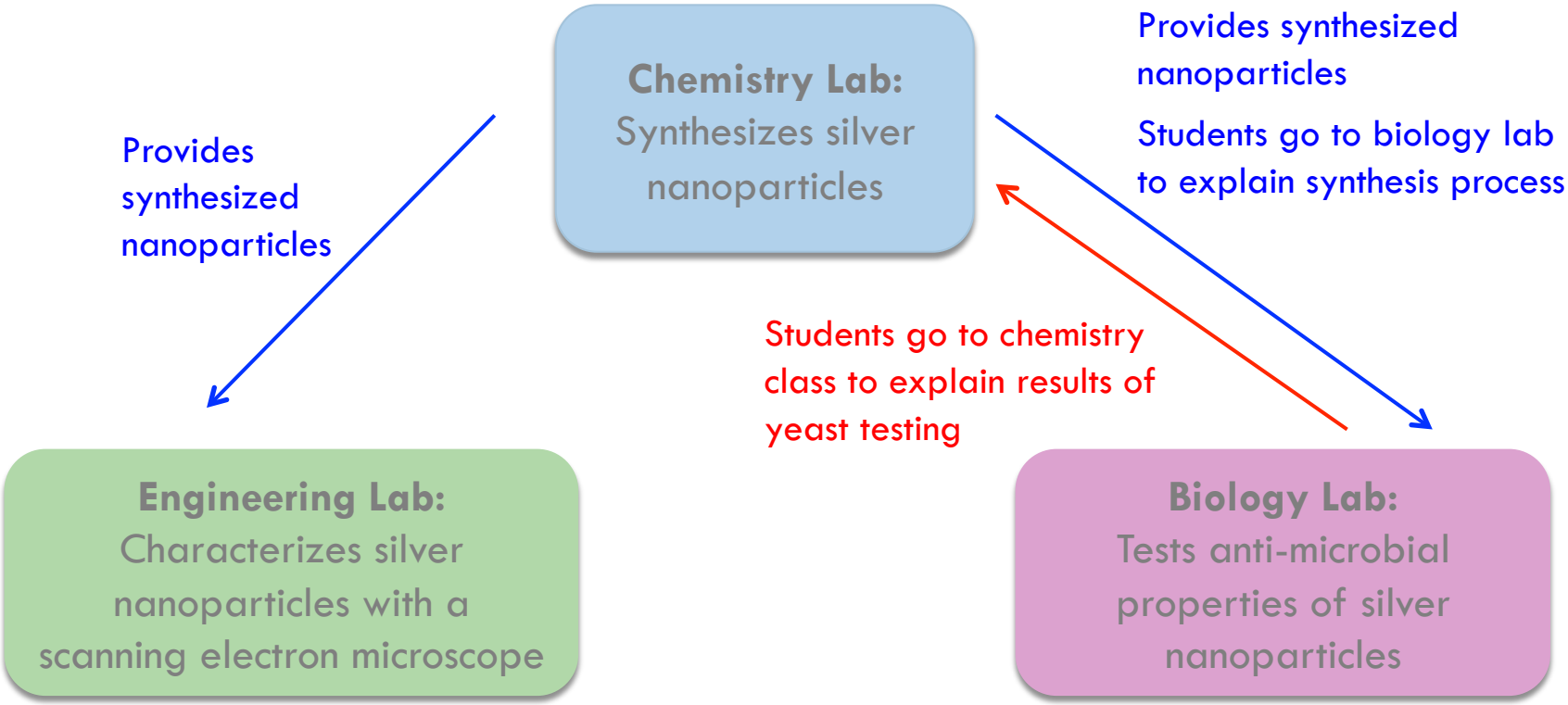
SYNTHESIS AND CHARACTERIZATION OF SILVER NANOPARTICLES

Lawrence Hall of Science, Spring 2013

Collaborative Lab Model

Due to the length and complexity of this lab, a collaborative model has been implemented, in which each disciplines has a specific role. An advantage of this collaborative model is that it helps introduce students to interdisciplinary research.



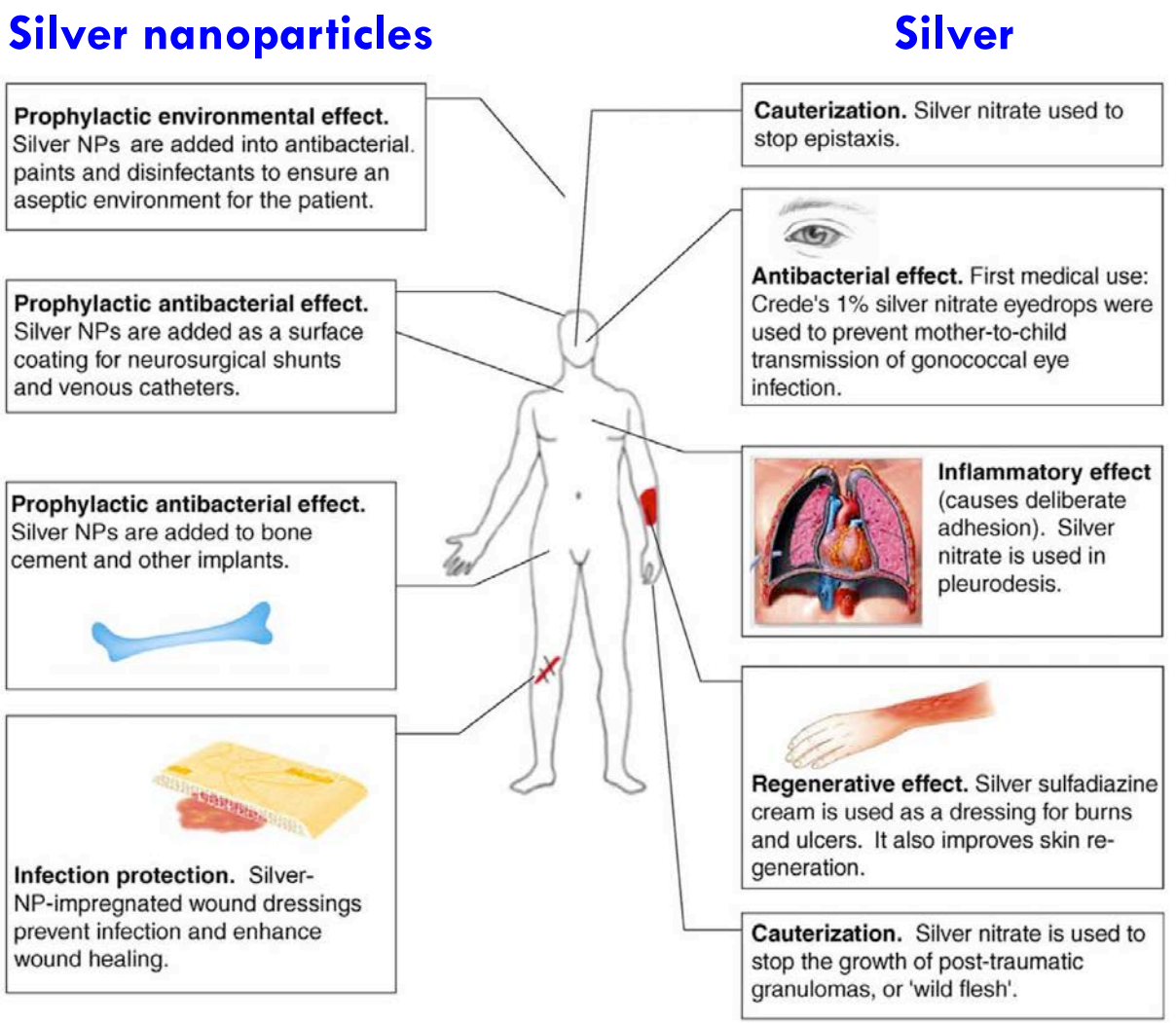
History of Silver

Silver has been used throughout history

- Greeks and Romans stored water in silver vessels
- 1800s: silver was used to treat ulcers
- 1880s: silver nitrate eye drops were given to newborns (now babies get antibiotic drops)
- 1920s: silver was used to manage wounds

Currently there are many products that use silver and silver nanoparticles

Uses of Silver and Silver Nanoparticles



Chaloupka *et al., Trends in Biotechnology,* 2010

Other Uses for Silver Nanoparticles

- Washing machines
- Hair straighteners
- Athletic clothing
- Socks

http://www.samsung.com/sg/consumer/learningresources/silvernano/silvernano/refigerator.html http://www.diabeticsock.com/products/Seamfree_Silver_Diabetic_Socks-27-6.html
http://cw-x.com/default.aspx http://www.conair.com/infiniti-nano-silver-by-conair-tourmaline-ceramic-1-straightener-p-563-1_73_12.html

Collaborative Lab Model

Chemistry Lab:
Synthesizes silver nanoparticles

Silver Nanoparticle Synthesis

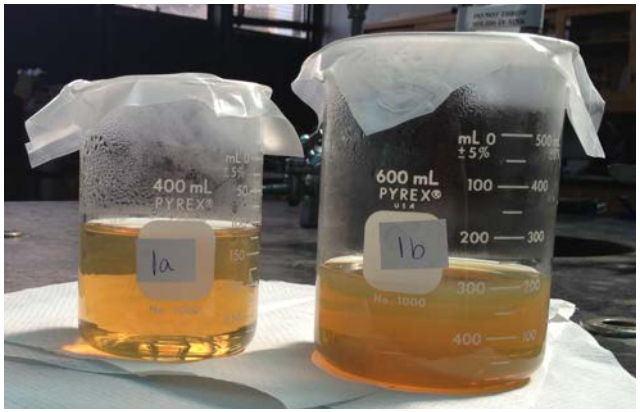
- Metallic nanoparticles can be synthesized through many methods

- The two most popular methods for synthesizing silver nanoparticles (Ag NP) via chemical reduction are:
  - Turkevich method (1951): Silver reduced by trisodium citrate
  - Brust method (1994): Silver reduced by sodium borohydride

- In this lab we're going to use the Turkevich method, since the materials are less hazardous

Turkevich Method for Ag NP Synthesis

- Boil 60mL of a 1mM silver nitrate solution, covered with a watch glass on a hot plate
  - Stir solution with a magnetic stir bar
- Once boiling, add 6mL of 10mM trisodium citrate dropwise, about 1 drop per second
- Replace watch glass
- Wait for solution to change to a light golden color
  - Carefully remove beaker from hot plate and let solution cool



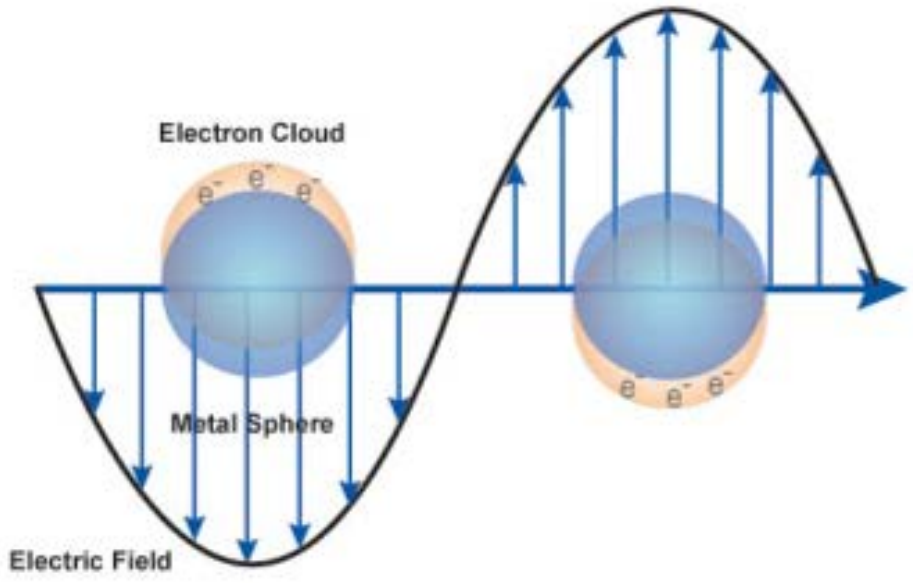
Reason for Color Change During Synthesis

At the *macroscale*, silver always looks like silver

But solutions of silver *nanoparticles* can have many colors!

http://nanocomposix.com/products/silver/spheres http://commons.wikimedia.org/wiki/File:Silver-nugget.jpg
http://www.sigmaaldrich.com/materials-science/nanomaterials/silver-nanoparticles.html

Surface Plasmon Resonance



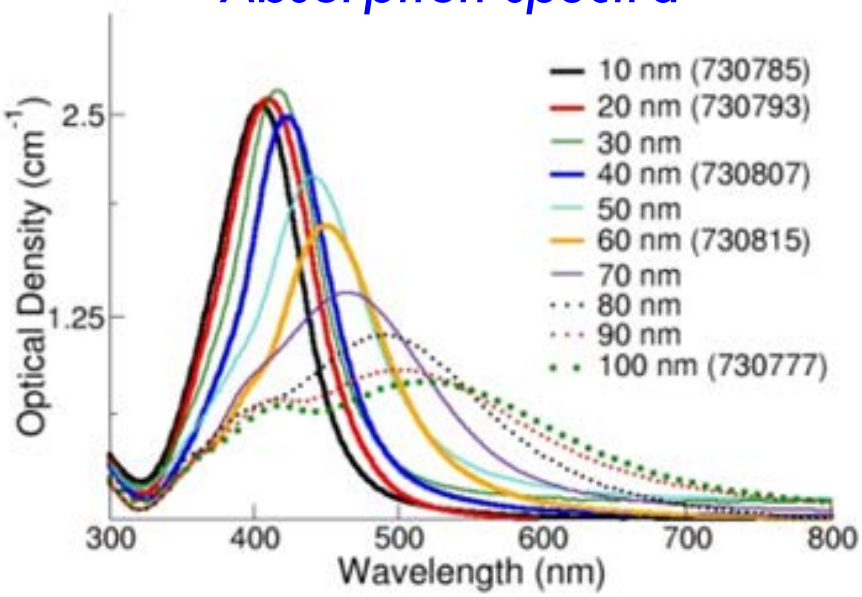
- In the silver nanoparticles, electrons oscillate collectively
- These oscillations affect how light interacts with the nanoparticles
- The specific oscillations depend on the particles' size and shape, so particles of different sizes have different colors

http://nanocomposix.com/products/silver/spheres http://commons.wikimedia.org/wiki/File:Silver-nugget.jpg
http://www.sigmaaldrich.com/materials-science/nanomaterials/silver-nanoparticles.html

Color Change Indicates Particle Size

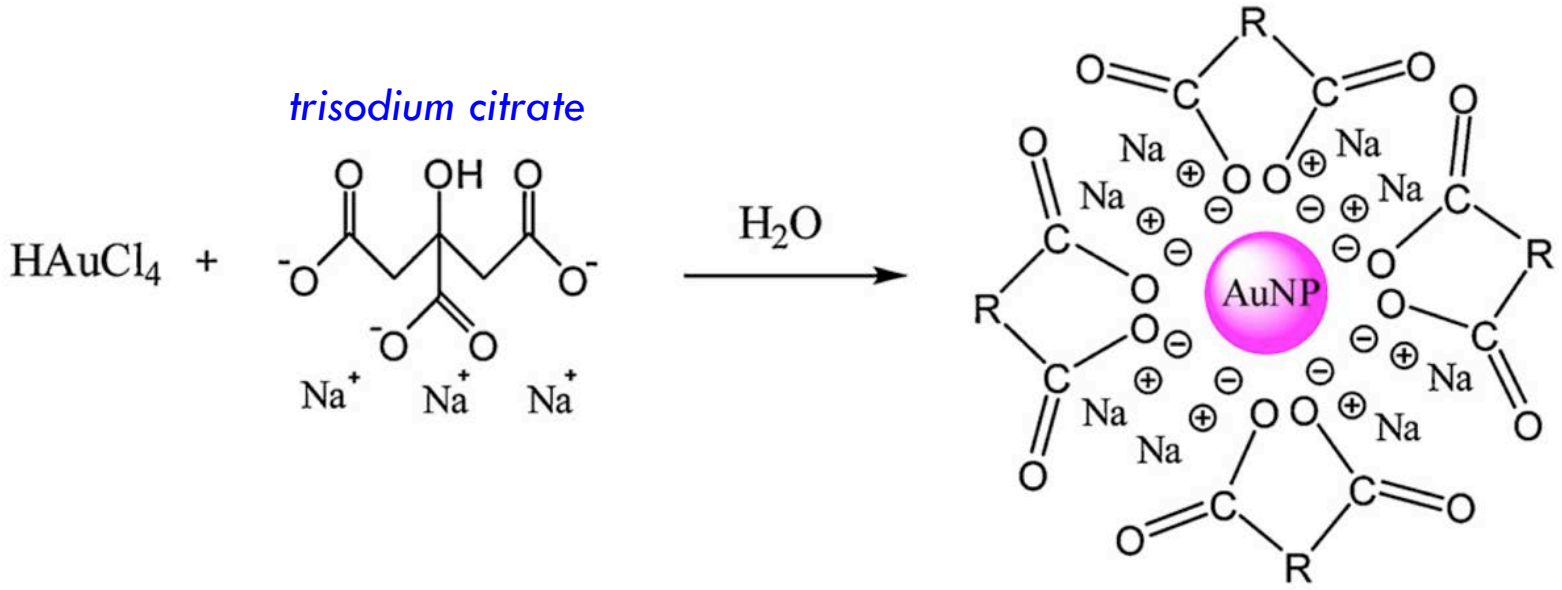
- Solution color gives an approximate idea of the particle size
- The color we see is basically an integration of the absorption spectra
- Nanoparticle size can be monitored more accurately by taking absorption spectra

Absorption spectra



http://www.sigmaaldrich.com/materials-science/nanomaterials/silver-nanoparticles.html

Role of Citrate



Citrate ions

-- reduce gold ions

-- cap the resulting nanoparticles

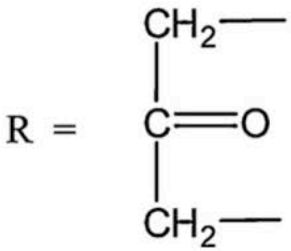
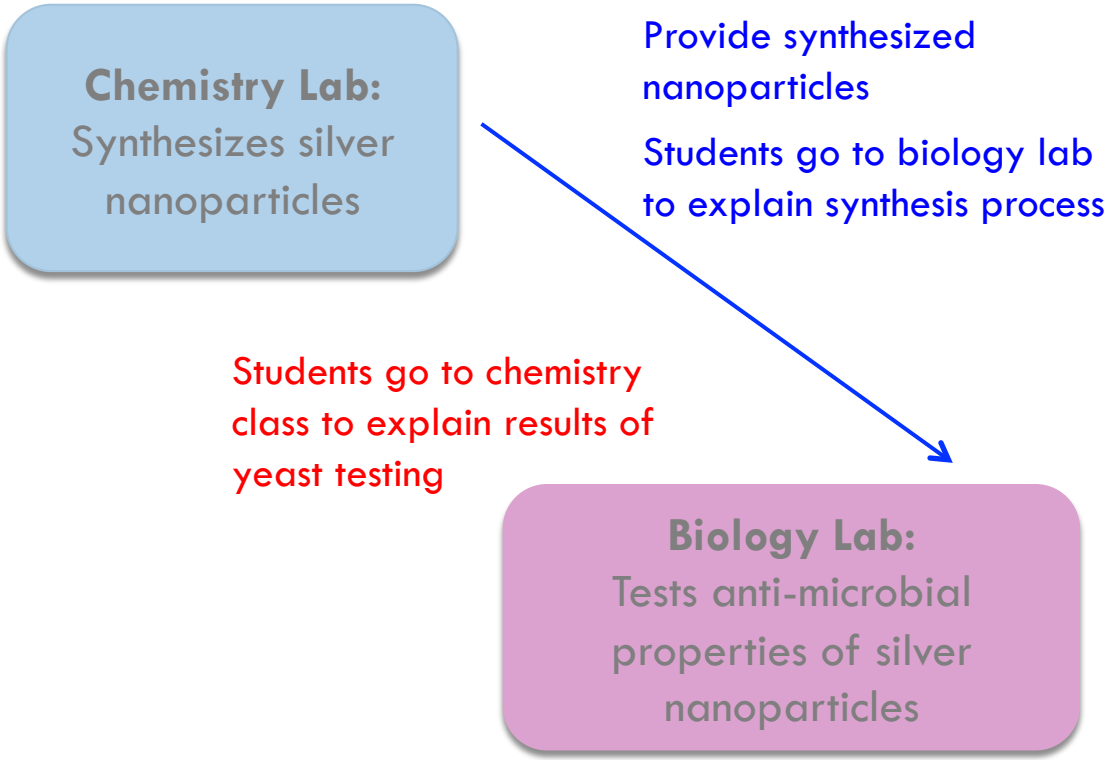


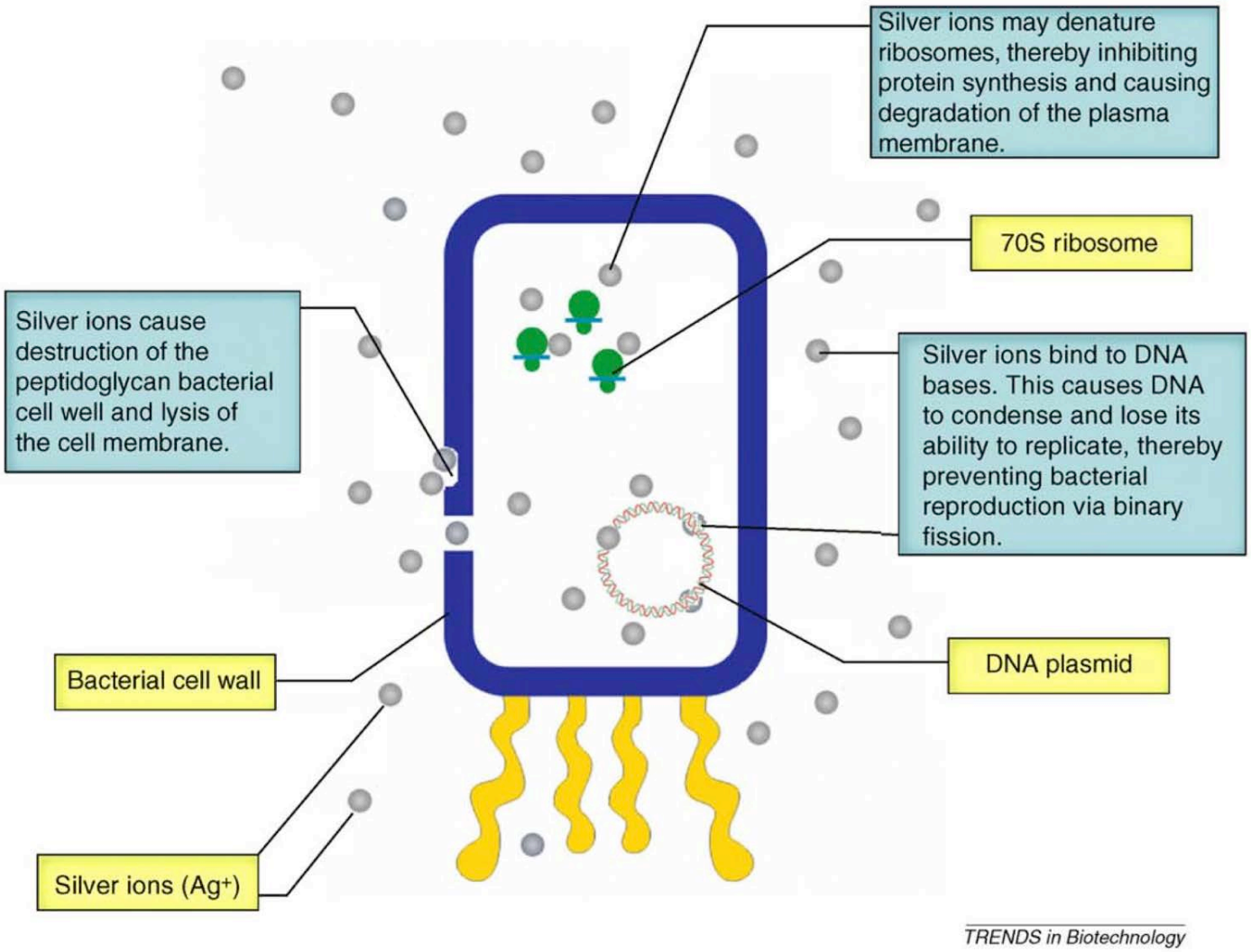
Fig. 1. AuNP synthesis using the Turkevich method.

Zhao, P., *et al*. "State of the art in gold nanoparticle synthesis." *Coordination Chemistry Reviews* 257 (2013), 638-665.

Collaborative Lab Model



How Silver Ions Kill Bacteria



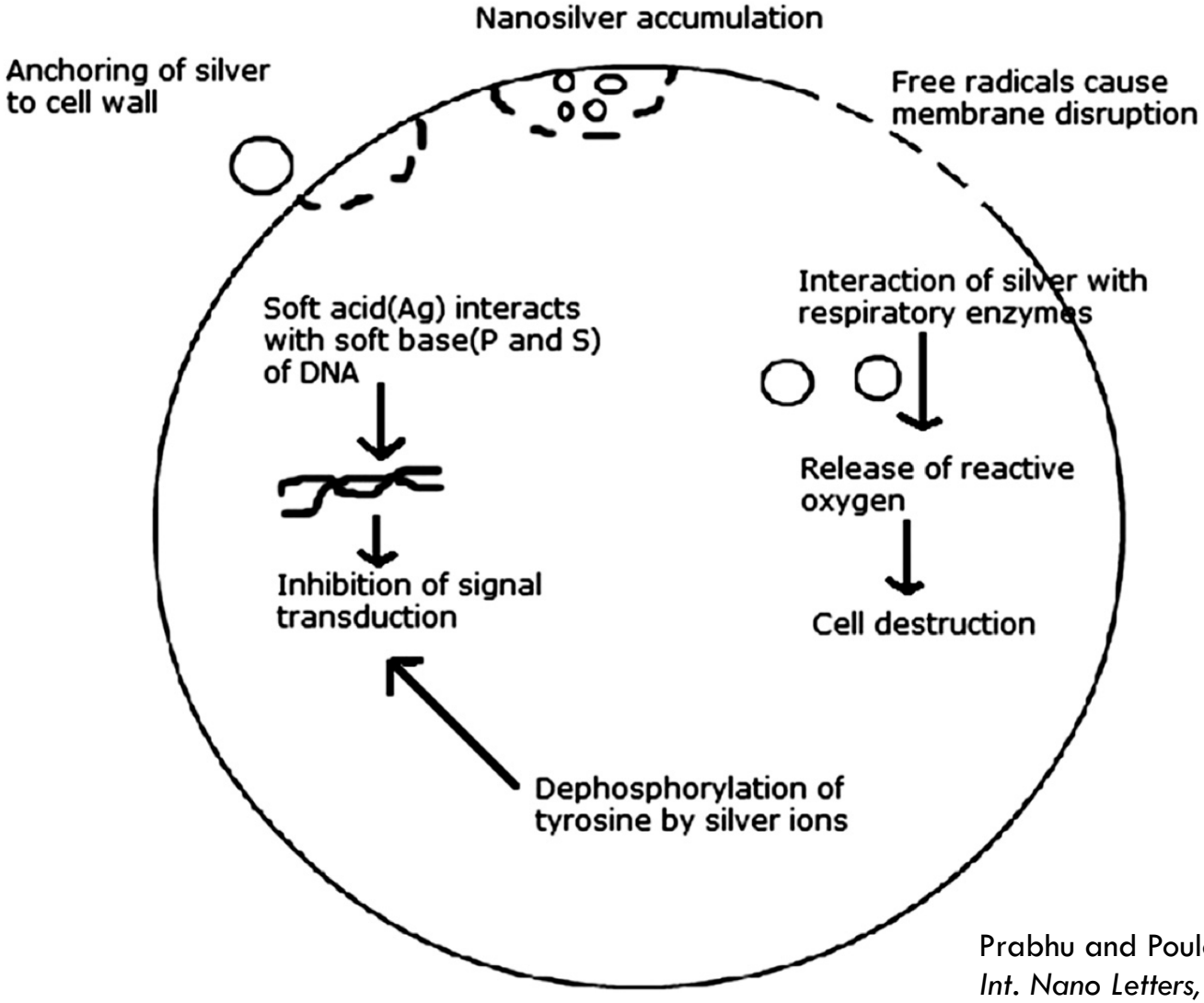
Chaloupka *et al.*, *Trends in Biotechnology*, 2010

Silver Ions vs Silver Nanoparticles

- The antimicrobial properties of silver nanoparticles (Ag NPs) are less understood

- Possible bactericidal mechanisms for Ag NPs include
  - Cell uptake followed by disruption of both ATP production and DNA replication
  - Cell membrane damage
  - Generation of reactive oxygen species

How Silver Nanoparticles Kill Bacteria



Prabhu and Poulose, *Int. Nano Letters,* 2012

Yeast Fermentation

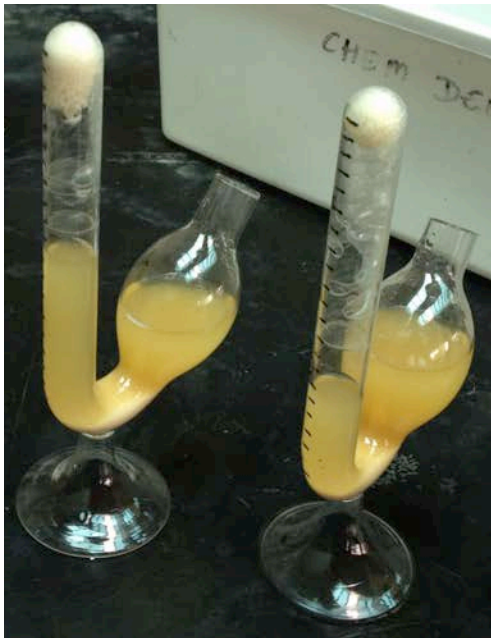
- The anti-microbial properties of the silver nanoparticles (Ag NP) can be tested by measuring how Ag NPs affect yeast respiration

- Yeast fermentation:

$$C_6H_{12}O_6 \rightarrow 2CO_2 \text{ (gas)} + 2 \text{ alcohol molecules}$$

- If Ag NPs kill yeast, there will be fewer yeast undergoing respiration, so the CO_2 production will be lower

- The CO_2 produced can be measured in yeast fermentation tubes by tracking gas bubble height

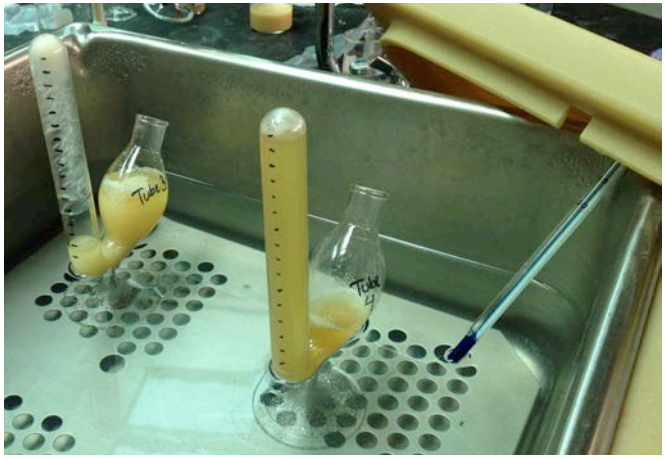


Yeast Fermentation

- Draw horizontal lines on fermentation tubes, (makes it easier to record bubble height data)
- Measure appropriate chemicals into beakers and stir to mix

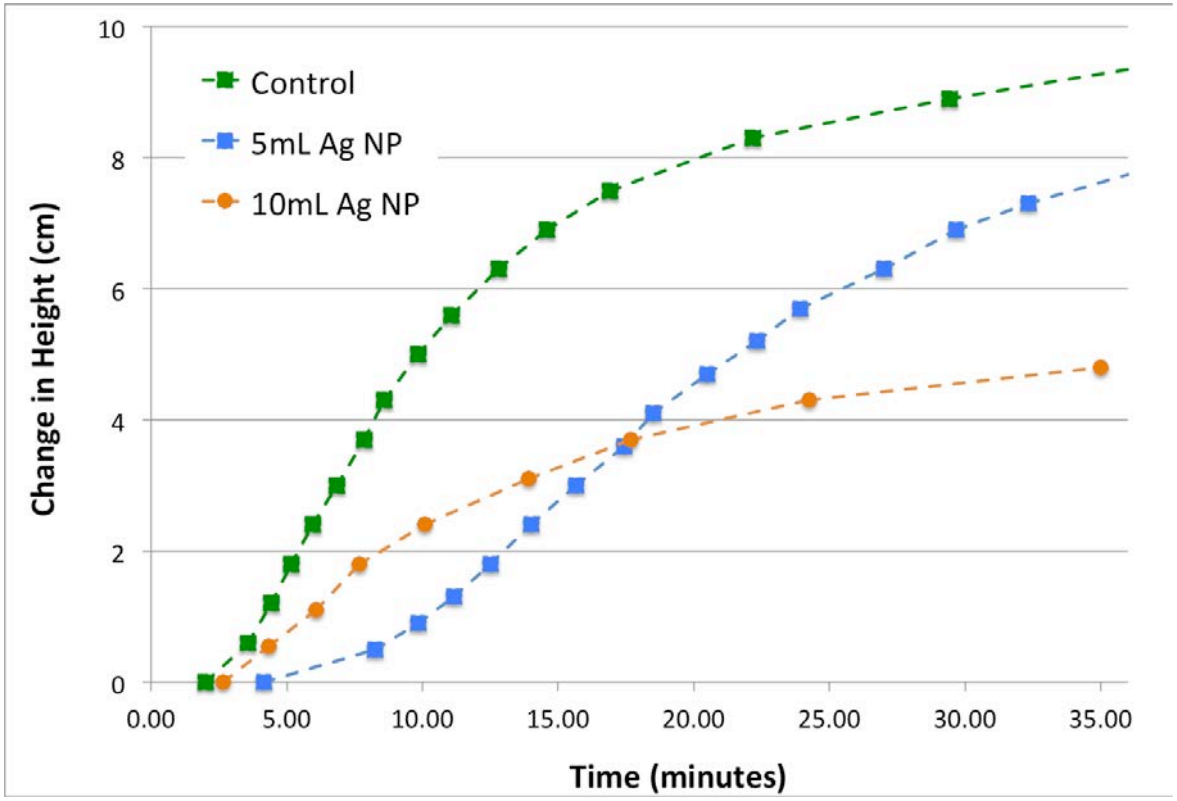
  control: water and yeast/molasses solution
  test: silver nanoparticles and yeast/molasses solution

- Pour mixtures from beakers into fermentation tubes, taking care to not get bubbles in the vertical portions
- Transfer fermentation tubes to a water bath (set to 50 °C)
- Monitor fermentation and record data



Sample Fermentation Data

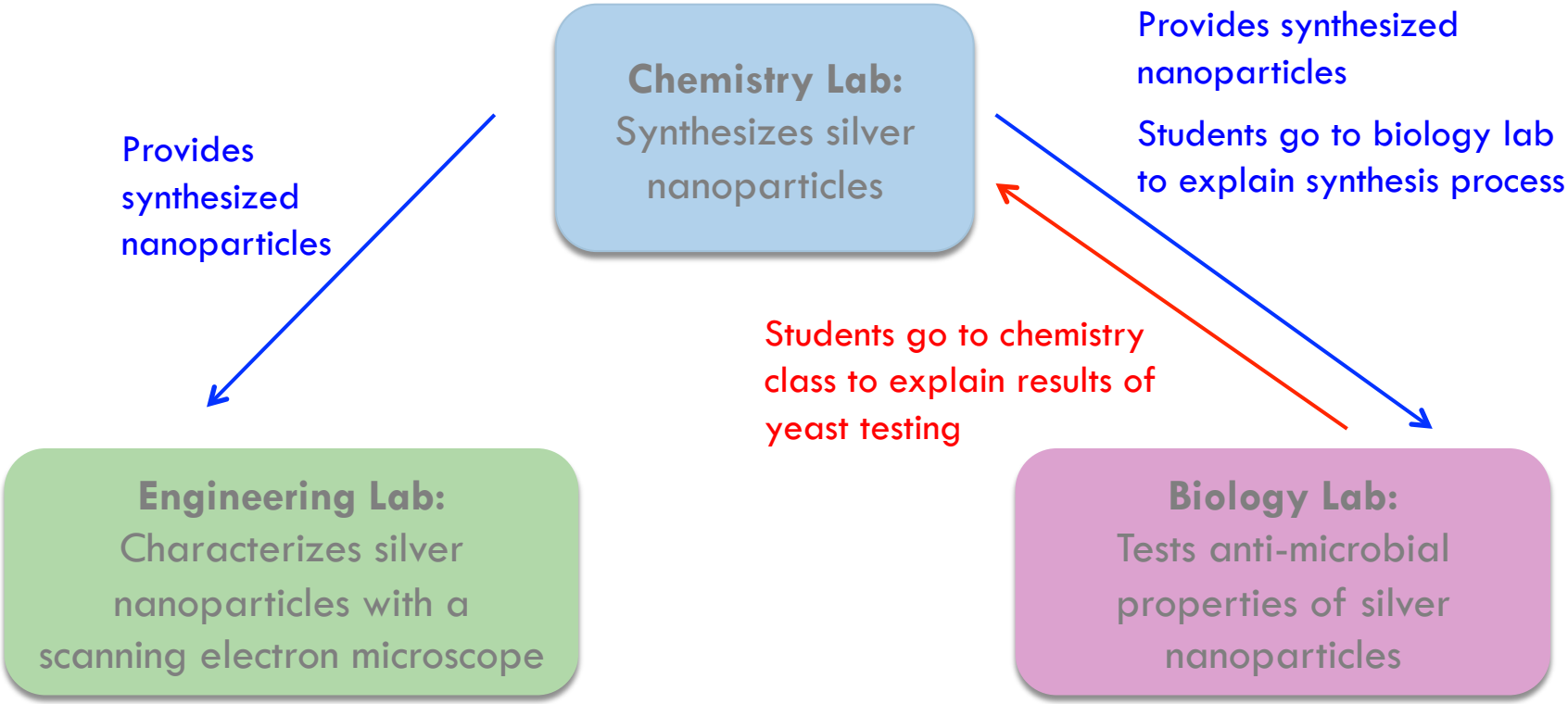
	Silver nanoparticles	Water	Yeast/molasses solution
Control	0	20 mL	20 mL
5ml silver NPs	5 mL	5 mL	20 mL
10ml silver NPs	10 mL	10 mL	20 mL



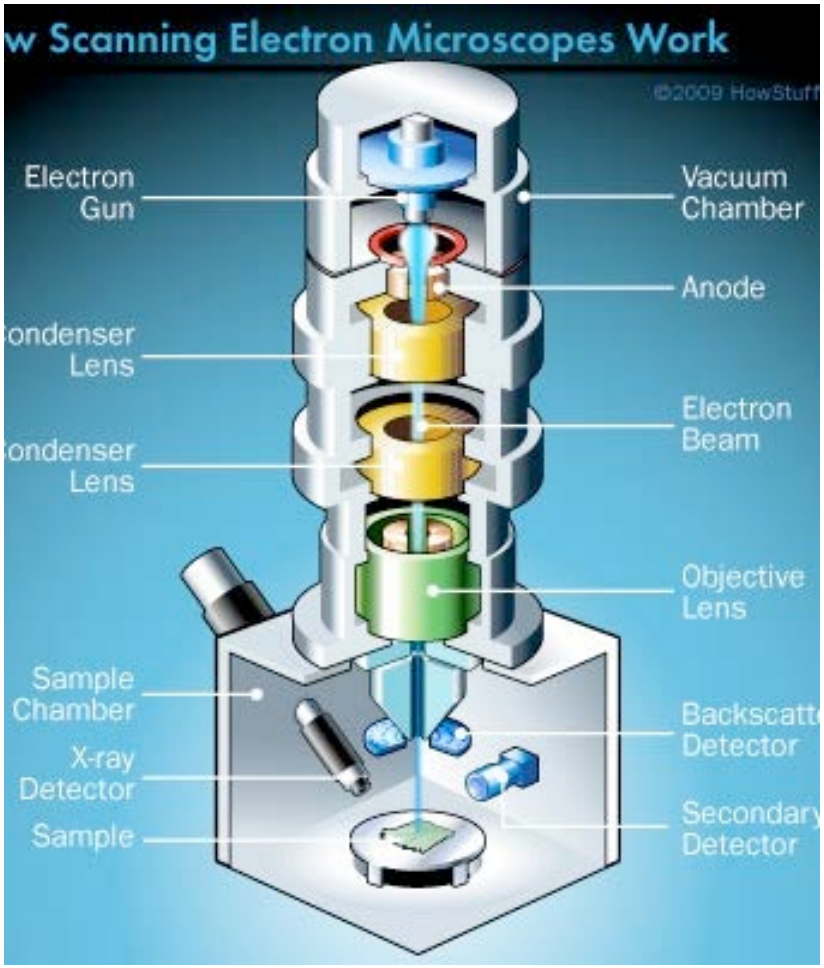
Sample data collection table

Tube 1 (control)	
Line	*Time*
start	*1:41:30 PM*
0	1:43:45 PM
1	1:45:35 PM
2	1:48:05 PM
3	1:52:25 PM
4	1:54:55 PM
5	1:58:06 PM
6	1:59:15 PM

Collaborative Lab Model



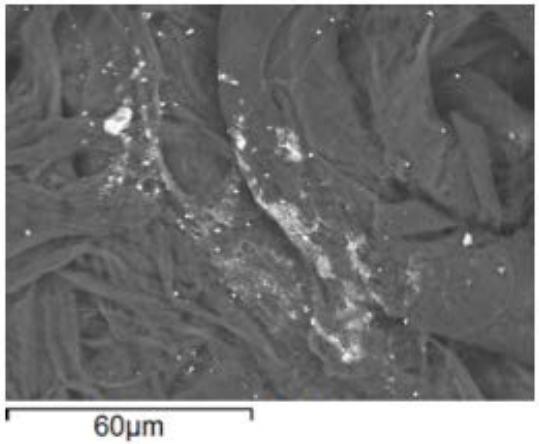
SEM Characterization



http://science.howstuffworks.com/scanning-electron-microscope2.htm

Use a Hitachi SEM (a TM3000) to characterize a filter paper soaked in silver nanoparticle solution

Sample SEM image



Considering Impacts of Technology

Values shape what technologies are developed and adopted.

Technologies affect social relationships.

Technologies work because they're part of systems

http://nisenet.org/catalog/tools_guides/nano_society_training_materials

Societal and Ethical Implications of Nano Silver

- Silver nanoparticles could affect individuals

  Overdose of *macro* silver causes Argyria

  Safety of *nano* silver still unknown

- Silver nanoparticles could also affect whole societies and ecosystems

  Silver nanoparticles can inhibit many bacteria, including "good bacteria"

  Silver nanoparticles can prevent photosynthesis in algae

Nano Around the World

- Available from http://www.nisenet.org/catalog/programs/nano_around_world
- Participants reflect on the potential uses of nanotechnology as they trade technology cards
- Fun way to reflect on the impacts of many technologies, not just nanotechnology

References

- Turkevich, T., *et al*. "A Study of the Nucleation and Growth Processes in the Synthesis of Colloidal Gold." *Discussions of the Faraday Society* 1951, Vol. 11, 55-75.
- Brust, M., *et al*. "Synthesis of Thiol-Derivatized Gold Nanoparticles in a Two phase Liquid-Liquid System." *J. Chem. Soc., Chem. Commun*. 1994, 801-802.
- To find more products that user nano silver, search this inventory of nanotechnology-based consumer products: http://www.nanotechproject.org/inventories/consumer/
- J. Alexander. "History of the Medical Use of Silver." *Surgical Infections* 2009, 289-292.
- Rai, M. and N. Duran. *Metal Nanoparticles in Microbiology*. 2011.
- "Antimicrobial Effects of Silver Nanoparticles". Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems. https://nano-cemms.illinois.edu/media/content/teaching_mats/online/antimicrobial_silver/docs/guide.pdf
- "Antimicrobial Silver Nanoparticles." nanoComposix. http://nanocomposix.com/technology/antimicrobial-silver-nanoparticles
- Kosinski, R. "Using Yeast Fermentation to Suggest and Then Challenge a Model." *Association for Biology Laboratory Education (ABLE) Proceedings* 2010, Vol. 31: 162-186.
- Navarro. E, *et al*. "Toxicity of Silver Nanoparticles to *Chlamydomonas reinhardtii*." *Environ. Sci. Technol*. 2008, Vol. 42: 8959-8964.