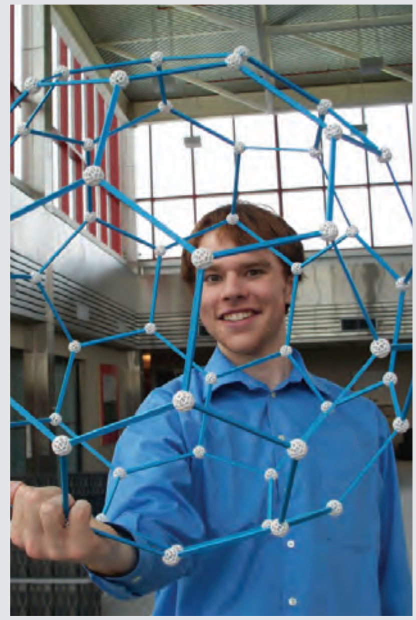
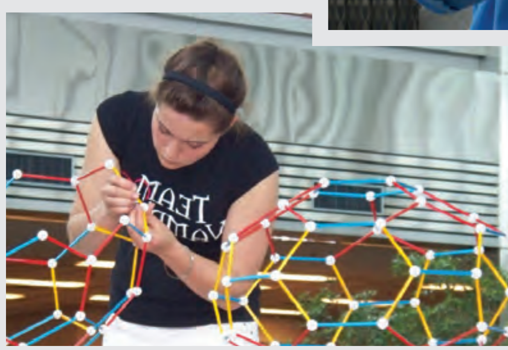
NANOTECHNOLOGY

LESSON PLANS GRADES 10, 11, 12





Alberta
Freedom To Create. Spirit To Achieve.

Alberta Innovates Technology Futures

Why Teach Your Students About Nanotechnology?

Science is changing at a vast pace with new discoveries and learning happening around the world daily. With this continual change in the field of science we also need to continually develop students' interest by engaging them in these new aspects and the applicability of science to their future. Be it in post-secondary options and work thereafter, our Alberta students have opportunities in this emerging field that can propel them into an incredible future.

The application of science at a molecular level, nanotechnology promises to dramatically impact the world in new and amazing ways. Advances in this field are revolutionizing medicine, energy production, environmental protection, bioindustries and more. Estimates have the global nanotechnology market reaching $1 trillion dollars by 2020. With established infrastructure and unique advantages in certain areas, Alberta is quickly becoming a world leader in the research, development, and commercialization of these new technologies. Alberta is home to Canada's National Institute for Nanotechnology, which houses both world-class researchers and state of the art equipment. The University of Alberta, the University of Calgary, and Northern Alberta Institute of Technology all offer nanotechnology programs to train the next generation of bright minds. A growing cluster of Alberta companies have already begun commercializing nanotechnology-enabled sensors, coatings, new materials and devices. To put it simply, nanotechnology is happening here!

As Alberta's nanotechnology capabilities grow there will be an increase in the demand for scientists and engineers. Some of the current occupations available today are Electron Microscopy Technician, Cancer Researcher and others. There will also be demand for politicians, lawyers, and business people with a keen understanding of nanotechnology and its impact on the world around. Occupations include Nanotechnology Entrepreneur, Nanotechnology Business Manager, Nanotechnology Economist and much more. To ensure Alberta students are equipped to thrive in a world of emerging technology, Alberta Innovates – Technology Futures has teamed up with Alberta Advanced Education and Technology and science teachers from across Alberta to develop a series of exciting and engaging nanotechnology lesson plans.

We hope you will enjoy our simple, "pick-up and go" lesson plans that will add science currency to your science program.

ISBN 978-0-7785-9660-8

1. Lesson planning – Alberta – Outlines, syllabi, etc.
2. Nanotechnology – Alberta –Curricula. I. Alberta. Alberta Advanced Education and Technology. II. Alberta Innovates –Technology Futures.

LB1027.4 N186 2011 371.3028

These lesson plans are available to view online and can be downloaded free at **nanolessonplans.alberta.ca**

Limited additional copies are available for ordering from the Learning Resource Centre at **lrc.education.gov.ab.ca**

For information, including reproduction for commercial purposes, please contact:
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Phone: 780-450-5111
Email: nano@albertainnovates.ca

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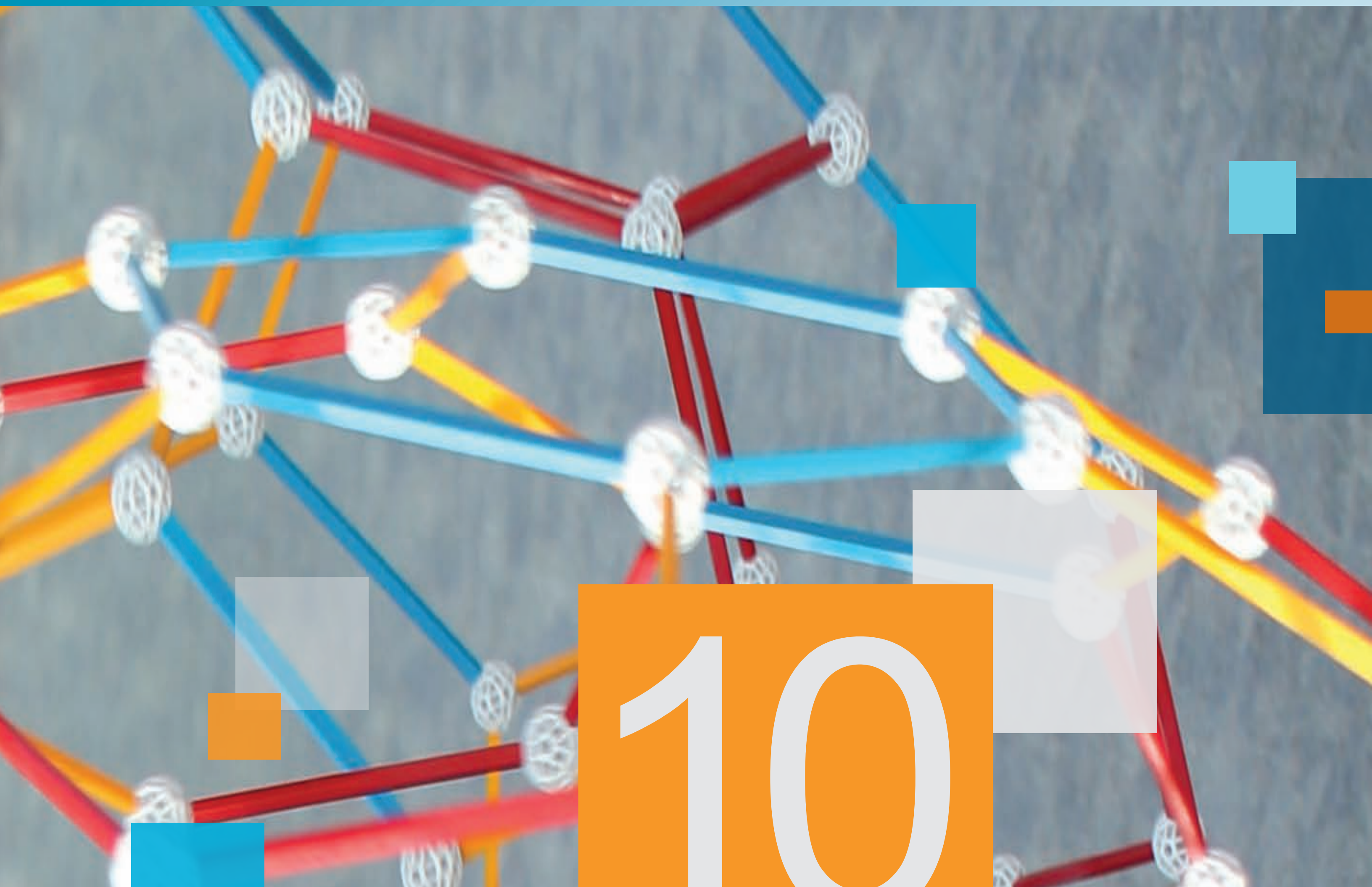
NANOTECHNOLOGY

LESSON PLAN FOR SCIENCE 10 - BRANEWORK



10

Alberta
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Science Teachers,

This lesson plan was designed for grade 10 and meets Alberta Education curriculum learning outcomes for science (see the following page for program of studies reference). The plans are easy to understand and implement without any specialized training, additional work or study. Best of all, they make this interesting subject matter engaging to teach.

The lesson plans were focus tested in seven schools throughout Alberta, incorporating teacher's feedback, and received great reviews. These plans provide the tools necessary to guide students through interactive experiences with nanotechnology that will help them understand this aspect of science. Included in the lesson plans are:

- a short explanation on what is nanotechnology,
- an activity description,
- time requirements,
- materials,
- an assessment rubric, and
- an in-depth teacher's background for reference.

Each lesson was designed in a way that allows you to quickly adapt it to your specific class needs and/or level of knowledge. If you wish to go deeper into the material, you can use the links provided under References or Bibliography. These lesson plans are complemented by a Nano Resource DVD for additional resources such as comic strips, videos, photos and more information related to teaching and understanding nanotechnology. These resources are also available for downloading at **nanolessonplans.alberta.ca**.

Did You Know?

The University of Alberta, the University of Calgary, and the Northern Alberta Institute of Technology all offer nanotechnology programs to train the next generation of curious and bright minds.

As you can see, the subject of nanotechnology is rich with opportunities for learning. We hope you will find the lesson plans worth implementing and include this fascinating area of science in your science program for the year.

If you require more information on additional nanotechnology learning experiences, or have any questions about the information provided, please contact nanoAlberta at 780-450-5111 or email nano@albertainnovates.ca. For grades 7 to 12 check out our travelling Scanning Electron Microscope (SEM) program and book it for your school today. This free program supplies the Microscope for a week and an Alberta certified science teacher will come and work with you and your class or school. A great complement to the nano lesson plans.
Visit **nanolessonplans.alberta.ca** for more information on the SEM program.

ISBN 978-0-7785-9673-8 (print)
ISBN 978-0-7785-9674-5 (online)

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Program of Studies Reference:
Science 10 – Cycling of Matter in Living Systems

Key Concepts
- Microscopy and the emergence of cell theory
- Cellular structures and functions and technological applications

Skills
- Initiating and Planning
- Reforming and recording
- Communications and Teamwork

Attitudes
- Interest in Science
- Collaboration
- Scientific Inquiry

STS
- Imaging technology and the current understanding of the cell
- Describe the function of cell organelles and structures

Check out these other great Nanotechnology Lesson Plans

Nanotechnology: Lesson Plan for Grade 4 Science
Slippery Leaves

Nanotechnology: Lesson Plan for Grade 5 Science
Small is Different–Classroom Chemistry

Nanotechnology: Lesson Plan for Grade 6 Science
Forestry Nano Superheroes–Trees and Forests

Nanotechnology: Lesson Plan for Grade 7 Science
Nanotechnology and the Environment – Smart Dust

Nanotechnology: Lesson Plan for Grade 8 Science
Nanovision–Light and Optical Systems

Nanotechnology: Lesson Plan for Grade 9 Science
Carbon's Nanocaper–Matter and Chemical Change

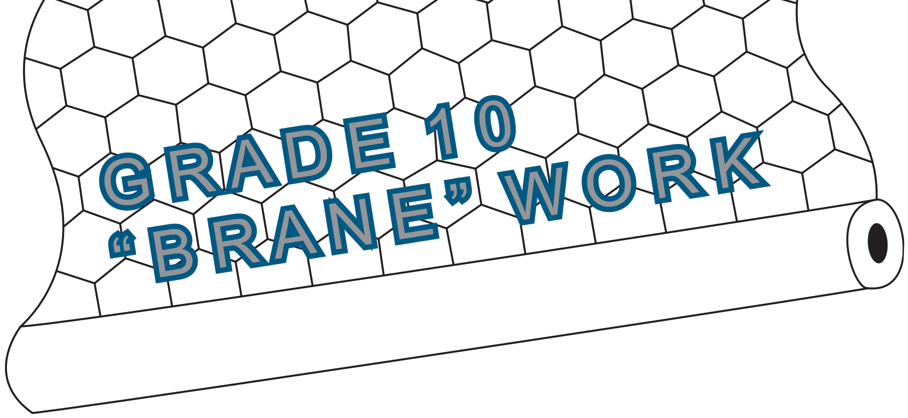
Nanotechnology: Lesson Plan for Chemistry 20
Putting it Together-Self Assembly
–The Diversity of Matter and Chemical Bonding

Nanotechnology: Lesson Plan for Biology 30
Medical Applications of Nanotechnology
–Cell Division, Genetics, and Molecular Biology

Did You Know?

Nanotechnology opens students to a wide variety of occupations in an even wider variety of industry sectors. Consider that nanotechnology may be encountered and used in some way by:

- Applications Technician
- Bio Material Engineer
- Cancer Researcher
- Characterization Scientist
- Chemical Technologist/Engineer
- Chemist
- Coating Scientist
- Computational Physicist
- Contact Metallization Process Engineer
- Electron Microscopy Technician
- Materials/Nanotechnology Scientist
- Materials/Metallurgical Engineer
- Mechanical Engineering
- Molecular Biologist
- Molecular Imaging Technologists
- Nanobiologist
- Nanoparticle Development Scientist
- Nanotechnology Business Manager
- Nanotechnology Laboratory Technician
- Nanotoxicologist
- Optical Engineer
- Pharmacologist
- Process Quality Engineer
- Product Marketing Manager
- Tissue Engineer
- Wafer Fabrication Development/Process Engineer



ACTIVITY DESCRIPTION

This activity has students take the information taught about cell structures (particularly, but not limited to, cell membranes) and use it to investigate how nanoscience and technology have used these basic principles to advance human and plant health and diagnostics. This is, after a brief introduction, a research project followed by a communication/presentation of results. It is recommended that students work in groups of not more than three.

Note that "brane" is used as an abbreviation of membrane, with "Brane Work" intentionally made to sound like "Brain Work".

TIME REQUIRED

80 minutes spread over two class periods, with a 1-2 week break in between.

- The first session introduces the concepts of nanoscience and nanotechnology and builds on the information already presented in class.
- The second session is used to present the results. Its length depends on the number of students in the class. Presentations of different types (PowerPoint, Skit, Pecha Kucha, video, etc.) are encouraged.

MATERIALS

This activity does not require in-class materials except those needed for developing presentations, and the student "teaser" sheets at the back of this lesson.

GLOSSARY
- nanoscience
- nanotechnology
- nanoparticles
- biomimicry
- quantum dots
- membranes

CLASS PREPARATION

Introduction

10 - 15 minutes

Introductory NanoScience PowerPoint Presentation

As an introduction to nanotechnology, teachers may wish to present the PowerPoint presentation created by NanoSense (SRI International) found at: http://nanosense.org/activities/sizematters/index.html under "Lesson 1—Introduction to Nanoscience".

Summarize cell structures and, particularly, cell membrane make-up, including markers or antigens on the cell membrane for immune system identification. Differences between the membrane composition of healthy cells, diseased cells, cancer cells, bacteria, and viruses can also be identified.

Antigens can be used to anchor drug delivery systems or nanoshells, which may be used in cell identification and destruction.

Student Sheet on biomarkers, quantum dots, and nanoshells

Student Sheet on water purification using membranes

Assessment:
- depth of research
- ability to communicate a scientific/technological topic clearly
- teamwork component
- general understanding of the topic
- ability to tie the nanotechnology research into the importance of understanding cell functions

ASSESSMENT

Example rubric.

Presentation: suitable for PowerPoint, Pecha Kucha, video, podcast

	POOR	FAIR	GOOD	EXEMPLARY
KNOWLEDGE	Group does not have grasp of information; questions cannot be answered	Group is uncomfortable with information and is only able to answer rudimentary questions	Group is at ease with content, but fails to elaborate	Group demonstrates full knowledge (more than required) with explanations and elaboration
LANGUAGE APPROPRIATE	Too many unexplained technical terms, or language at a very young level	Most technical terms explained; language within a few years of appropriate	All technical terms explained; language age- and grade-appropriate	Technical terms explained in context; language appropriate
DELIVERY (PRESENTATION STYLE)	Mumbling, incorrect pronunciation, too quiet to hear; transition between presenters chaotic	Incorrect pronunciation; audience may not hear presentation; transition between presenters rough	Clear; few stumbles with the information; transitions between presenters smooth	No stumbles; clear voice; transitions between presenters appear seamless
MECHANICS	Lots of spelling and grammar mistakes	A few mistakes	Fewer than 5 mistakes	No mistakes
ORGANIZATION	No sequence of information	Student jumps around through information	Information presented in a logical sequence	Information presented in a logical and interesting sequence

RESOURCES

http://www.albertatechfutures.ca/nanoAlberta/AlbertaNanoAssetMap.aspx

http://www.wisc-online.com/objects/ViewObject.aspx?ID=NAN405

Dr. Ted Sargent's *The Dance of the Molecules* is a good source of information on the possibilities of nanotechnology.

A slide show on nanotechnology as it is applied to cancer and health. This slide show can be modified as needed, as long as the National Cancer Institute logos are not removed.
http://www.cancer.gov/cancertopics/understandingcancer/nanodevices/allpages

BIBLIOGRAPHY

1. "Size Matters: Introduction to Nanoscience." *NanoSense.* 15 November 2007. Web. 14 April 2011.
   http://nanosense.org/activities/sizematters/index.html

2. Sargent, Ted. *The Dance of the Molecules: How Nanotechnology is Changing Our Lives.* New York: Basic Books, 2006. (ISBN-10: 1560258098 ISBN-13: 978-1560258094)

3. "Understanding Cancer Series: Nanodevices." *National Cancer Institute.* n.d. Web. 14 April 2011.
   http://www.cancer.gov/cancertopics/understandingcancer/nanodevices/allpages

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6. Abraham, M. "Nanotech Water Desalination Membrane." *Nanotechnology* Today. 6 November 2006. Web. 14 April 2011.
   http://nanotechnologytoday.blogspot.com/2006/11/nanotech-water-desalination-membrane.html

STUDENT SHEET

Biomarkers, Quantum dots, and nanoshells

Adapted from http://www.cancer.gov/cancertopics/understandingcancer/nanodevices

Every cell whether animal, plant, bacteria or virus covering has a distinct membrane that identifies the organism. The make-up of the membrane is a lipid boundary (like a wall) with proteins that act as gatekeepers to allow materials to flow in and out of the cell. To attract material to the cell, the cell membrane also has other unique proteins that connect to the cell wall. These proteins identify the unique nature of the cell. Biomarkers are chemicals that bond to these unique proteins.

Proteins on the surface of cancerous cells are different in some ways to the proteins on the surface of healthy cells. Being able to identify the cancerous cells proteins and bind them to antibodies, drugs, or other agents will kill the cancerous cells. There are a number of different approaches that can be taken to identify and bind them.

Identification for surgical removal (using quantum dots)

A minuscule molecule that can be used to detect cancer is a quantum dot. Quantum dots are tiny crystals that glow when they are stimulated by ultraviolet light. The wavelength (or colour) of the light depends on the size of the crystal. Latex beads filled with these crystals can be designed to bind to specific DNA sequences (or proteins). By combining different-sized quantum dots within a single bead, scientists can create probes that release distinct colours and intensities of light. When the crystals are stimulated by UV light, each bead emits light that serves as a sort of spectral bar code, identifying a particular region of DNA.

Quantum dots can be bound to cancerous cells so that all of the cancerous cells can be identified during surgery and the surgeon will only remove the cancerous ones—not the normal ones.

Binding of diseased/cancerous cells with nanoshells

Nanoshells are miniscule beads coated with gold. By manipulating the thickness of the layers making up the nanoshells, scientists can design these beads to absorb specific wavelengths of light. The most useful nanoshells are those that absorb near-infrared light, which can easily penetrate several centimetres of human tissue. The absorption of light by the nanoshells creates an intense heat that is lethal to cells.

Researchers can already link nanoshells to antibodies that recognize cancer cells. Scientists envision letting these nanoshells seek out their cancerous targets, then applying near-infrared light. In laboratory cultures, the heat generated by the light-absorbing nanoshells has successfully killed tumour cells while leaving neighbouring cells intact.

STUDENT SHEET

Membranes for water purification, desalinization

A large percentage of the Earth's water is contaminated with dissolved salts and minerals or pathogens.

Osmosis

The passage of water from a region of high water concentration to a region of low water concentration, through a semi-permeable membrane. The cell membrane is a semi-permeable membrane. This process allows the cell to stay filled with water, which is important since cell activities go on in a water-filled (aqueous) solution. This activity occurs naturally in a cell.

Reverse osmosis

To move water from a region of lower concentration to one of higher concentration (such as a region where water is contaminated with dirt, viruses, bacteria, or salts to a region of pure water), a semi-permeable membrane can again be used. The process does not occur naturally, however—energy must be used to force the water through the membrane. The membrane must prevent contamination from passing through it, and nanotechnology can be used to help develop membranes that can do that.

Types of nanotechnology membranes

While cell membranes are made of lipids with protein-controlled openings to let resources in and waste out, non-organic membranes that behave similarly can be made of many different materials. A nanotechnology tool that can be used for this purpose is a carbon nanotube.

Carbon nanotubes

The nanotubes (sheets of graphene rolled into a tube) are arranged so that they are closely packed together, which allows water to flow through them as if traversing a pile of straws. The opening of the nanotubes is only a few nanometers wide, so that water molecules can pass through them, but bacteria, biological material, and other impurities cannot. Thus, the water obtained after passing through the nanotube is clear of impurities.

Traditional membranes capture the impurities within the membrane, so it requires cleaning or back flushing. But the impurities are kept out of the nanotubes entirely, so that cleaning is more easily done.

Another possible application of such filters is water desalinization
http://www.nanobugle.org/2009/09/carbon-nanotube-membranes-for-water-purification/

Polymers and engineered nanoparticles

At the following link, there is a description of an engineered membrane that uses carefully-designed nanoparticles to attract and retain water while repelling salts and impurities. By developing membranes that are porous and hydrophilic, a more efficient reverse osmosis process could be achieved.

http://nanotechnologytoday.blogspot.com/2006/11/nanotech-water-desalination-membrane.html

NOTES:

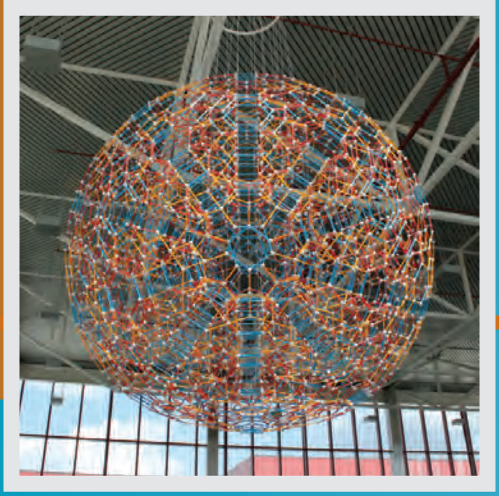
WHAT YOU'LL FIND HERE

- a "pick-up-and-go" lesson plan that will add science currency to your science program
- activities that meet science curriculum learning outcomes
- interesting subject matter that is engaging to teach
- easy to implement experiments (no specialized training needed)
- a quickly adaptable lesson with worksheets and rubrics for your class needs

Nano is... the scientific term meaning one-billionth (1/1,000,000,000). It comes from the Greek word meaning "dwarf".

Nano Science is... the discovery, research and understanding of all things nano.

Nanotechnology is... the application of science at the molecular level.

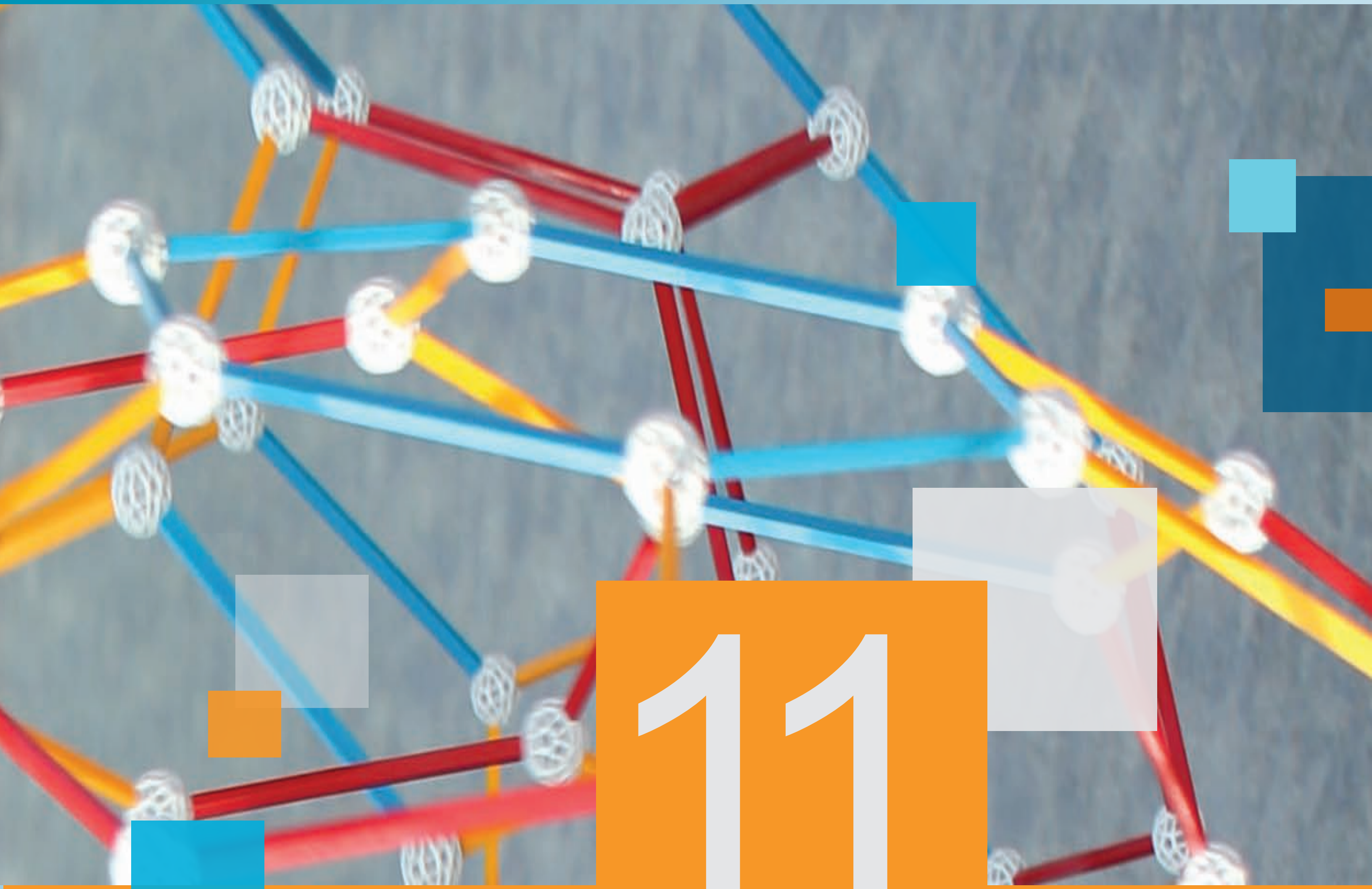


Nanotechnology is revolutionizing medicine, energy production, environmental protection, bioindustries and more!

Government of Alberta

NANOTECHNOLOGY

LESSON PLAN FOR CHEMISTRY 20 (SCIENCE 24) - PUTTING IT TOGETHER



11

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Science Teachers,

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The lesson plans were focus tested in seven schools throughout Alberta, incorporating teacher's feedback, and received great reviews. These plans provide the tools necessary to guide students through interactive experiences with nanotechnology that will help them understand this aspect of science. Included in the lesson plans are:

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- an activity description,
- time requirements,
- materials,
- an assessment rubric, and
- an in-depth teacher's background for reference.

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Visit **nanolessonplans.alberta.ca** for more information on the SEM program.

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Program of Studies Reference:
Chemistry 20 / Science 24 - The Diversity of Matter and Chemical Bonding

Key Concepts
- Intramolecular and intermolecular forces
- Hydrogen bonds
- Electronegativity
- Polarity
- Thermal energy

Skills
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

Knowledge
- Explain intermolecular forces
- Illustrate by drawing or building models

STS
- Investigate how basic knowledge about the structure of matter is advanced through nanotechnology research and development.

NOTE:
This lesson plan also meets the learning outcomes for a chemistry component in the Science 24 curriculum. Teachers may need to modify the lesson dependent on the class.

NOTE:
Grade 9 Nano lesson plan, Carbon's Nanocaper-Matter and Chemical Change, also meets the learning outcomes for Chemistry 20, available for downloading at **nanolessonplans.alberta.ca**

Check out these other great Nanotechnology Lesson Plans

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Slippery Leaves

Nanotechnology: Lesson Plan for Grade 5 Science
Small is Different–Classroom Chemistry

Nanotechnology: Lesson Plan for Grade 6 Science
Forestry Nano Superheroes–Trees and Forests

Nanotechnology: Lesson Plan for Grade 7 Science
Nanotechnology and the Environment – Smart Dust

Nanotechnology: Lesson Plan for Grade 8 Science
Nanovision–Light and Optical Systems

Nanotechnology: Lesson Plan for Grade 9 Science
Carbon's Nanocaper–Matter and Chemical Change

Nanotechnology: Lesson Plan for Science 10
"BRANE" Work–Cycling of Matter in Living Systems

Nanotechnology: Lesson Plan for Biology 30
Medical Applications of Nanotechnology
–Cell Division, Genetics, and Molecular Biology

ACTIVITY DESCRIPTION

This activity challenges students to build self-assembling structures using LEGO® blocks and Velcro or magnets. It uses modelling to show students how intermolecular bonding and hydrogen bonds are applied in self-assembly at the nanoscale level. Students design and build these structures and present them to the class, defending their designs and describing their understanding of the self-assembly process.

Adapted from: "How Nature Builds Itself: Self-Assembly" in the book *Nanoscale Science: Activities for Grades 6-12* by M. Gail Jones, Michael R. Falvo, Amy R. Taylor, and Bethany P. Broadwell.

MATERIALS

- LEGO® blocks
- small magnets
- superglue or glue guns
- paper
- scissors
- Student Sheets (included)

GLOSSARY

- self-assembly
- lock and key
- hydrogen bond
- intermolecular force

TIME REQUIRED

90 minutes

Did You Know?

Nanotechnology opens students to a wide variety of occupations in an even wider variety of industry sectors. Consider that nanotechnology may be encountered and used in some way by:

- Applications Technician
- Bio Material Engineer
- Cancer Researcher
- Characterization Scientist
- Chemical Technologist/Engineer
- Chemist
- Coating Scientist
- Computational Physicist
- Contact Metallization Process Engineer
- Electron Microscopy Technician
- Materials/Nanotechnology Scientist
- Materials/Metallurgical Engineer
- Mechanical Engineering
- Molecular Biologist
- Molecular Imaging Technologists
- Nanobiologist
- Nanoparticle Development Scientist
- Nanotechnology Business Manager
- Nanotechnology Laboratory Technician
- Nanotoxicologist
- Optical Engineer
- Pharmacologist
- Process Quality Engineer
- Product Marketing Manager
- Tissue Engineer
- Wafer Fabrication Development/Process Engineer

INTRODUCTORY POWERPOINT PRESENTATION:

As an introduction to nanotechnology, teachers may wish to present a PowerPoint presentation created by NanoSense (SRI International) found at: http://nanosense.org/activities/sizematters/index.html, under "Lesson 1—Introduction to Nanoscience".The information in this PPT is good but it is not particularly dynamic.

Teacher background

To get the most from this activity, students should have already investigated the structure of matter as it applies to organic (carbon-based) molecules. This may include intramolecular and intermolecular forces, hydrogen bonding, and the concept of electronegativity.

SELF-ASSEMBLY

> "Under specific conditions, some materials can spontaneously assemble into organized structures. This process provides a useful means for manipulating matter at the nanoscale."
> - *The Big ideas in Nanoscale Science and Engineering (p. 43)*

Self-assembly is the process by which materials build themselves without assistance. In the world of nanoscience, self-assembly is a "bottom-up" manufacturing process (using smaller components to build larger ones). Self-assembly is also the process by which natural materials, such as viruses, cells, and bones, are built in nature. It also plays a part in how viruses bond to a cell or how a drug finds its target. DNA replication is another example of self-assembly.

It is the intermolecular bonds that allow things at the nanoscale to stick together. These are the weaker bonds, such as hydrogen bonds, van der Waals bonding, and hydrophilic/hydrophobic interactions. It is the polarizable characteristic of molecules that gives rise to such intermolecular bonds. Some kind of intermolecular attraction will occur between any two molecules, and it is the weak character of these bonds that propels self-assembly.

The characteristics of the molecules (size, shape, and arrangement) and the environments they exist in (temperature, concentration of components, polarity, and acidity of the solvent) are critical to self-assembly processes. The process is pushed by the attracting and repelling forces between the building blocks and molecules.

Source: The Big ideas in Nanoscale Science and Engineering

LOCK AND KEY MECHANISMS

The shape of building blocks is a critical part of the self-assembly process. If the blocks have complementary shapes, it will make for easier access to the weaker non-covalent interactions (electrostatic forces, van der Waal's forces, hydrogen bonding, and hydrophobic interactions) that are the basis for self-assembly. When the shape of building blocks is complementary, the blocks are brought closer to each other and intermolecular forces can therefore take effect.

Source: http://www.physics.unc.edu/~falvo/Phys53_Spring11/Projects_Assignments/2006_Self_Assembly_How_Nature_Builds_Science_Teacher_2006.pdf

Nanotechnology Applications

Self-assembly is an example of the "bottom-up" manufacturing process used in nanoscale science and engineering. It involves building up larger structures from smaller ones at the atomic level. In this method, building blocks are purposely manipulated to form larger products. It is the net attractive forces of the components that bring and keep them together to form stable assembled structures. Bottom-up manufacturing is used to create nanotubes, nanowalls, and microfluidic channels for Lab on a Chip applications, to name just three examples.

Source:
- nanowalls: www.nanowerk.com/spotlight/spotid=9020.php
- microfluidic channels: http://pubs.acs.org/doi/abs/10.1021/cm101502n

The other method used is 'top-down". This is also called lithography, and involves taking away or "carving" away from an object to reach a final product. One example of a top-down process is photolithography. This uses a substrate surfaced with a photoresist coating. A mask (like a stencil) is placed on top and exposed to radiation. The mask only allows the desired pattern to be exposed to the radiation. The surface is then subjected to a chemical that removes either the exposed or the unexposed portion of the surface.

Source:

Stevens, S. Y., Sutherland, L., Schank, P., & Krajcik, J. (2007). T*he Big ideas in Nanoscale Science and Engineering.*

Try this neat game that illustrates some examples of self-assembly:
http://molit.concord.org/database/activities/231.html

ALBERTA RESEARCHERS

Dr. Larry Unsworth, of the University of Alberta's Department of Chemical and Materials Engineering and the National Institute for Nanotechnology (NINT), is investigating self-assembly processes in the engineering of peptides that can attach to and destroy bacterial cells. This research has the potential to create ways to combat drug resistant strains of bacteria (www.ualberta.ca/~lunswort/index.html - contact information).

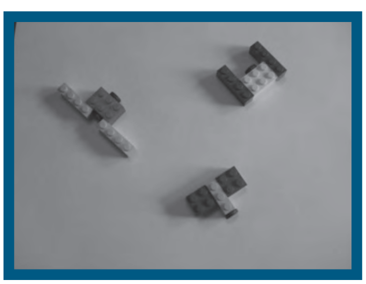
CLASS PREPARATION - Introduction

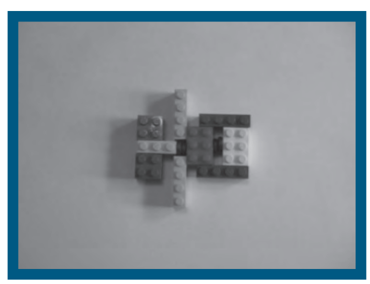
15-20 minutes

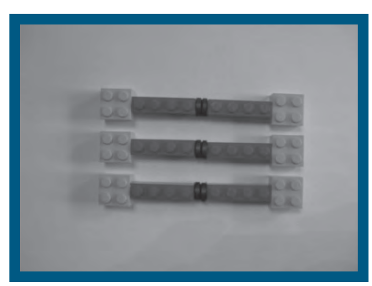
It is assumed that the basic molecular chemistry of bonding has already been presented. This activity will identify the extent to which students have grasped that content.

MODEL DESIGN

The task is to design a 3 dimensional, self-assembling model with two, three, four or more pieces that come together in a particular way—like jigsaw puzzle pieces. Students can start designing using paper cut-outs. This will help them work out the intermolecular bonds and the logic of the bonding patterns, and will help them ensure that pieces bond where they want them to. Models can be molecular models or simply geometric shapes. The trick is to use multiple weak bonds and shapes that fit together (lock and key).







MODEL-BUILDING

This step involves gluing the magnets to the LEGO® pieces. Remind students to use the polarity of the magnets to facilitate self-assembly. Superglue works best to ensure that the pieces can withstand the "thermal energy" created when shaking the reaction chamber.

REACTION CHAMBER

There are several possibilities for reaction chambers: shoeboxes (students can bring these from home), pizza boxes (a pizza store might donate some clean ones), clear plastic containers with lids (these would allow students to see the process through the sides).

The least complicated model involves shaking only from side to side. Pieces are placed inside the chamber separately and arranged randomly. The chamber is placed on a desk or table and slid back and forth in random directions. More vigorous shaking of the box represents a higher temperature, and should work to break down any bonds the students did not intend to happen. It may take a number of tries to get the result the students had planned. Reassure students that if their models work one in five times, they've built a good one.

MODEL PRESENTATION

Have students present and demonstrate their models for the class. They will need to explain the self-assembly process in their presentations, using the new concepts of weak bonds and compatibility of shape.

ASSESSMENT

SUMMATIVE ASSESSMENT

One possibility is for the teacher to create a number of models—some that self-assemble and some that don't. Students would need to explain, in terms of bonding and geometric shape, why the models work or do not.

Some questions they would need to be able to answer include:

1. Explain the role of the LEGO® in the activity.
   They are the molecules or the building blocks.

2. What do the magnets represent?
   They take the place of the receptor sites on the molecules.

3. What does the container represent?
   The environment where the reaction is happening.

4. When you shake the container, what are you simulating?
   This represents the thermal energy that happens at the nanometre scale that causes the molecules and building blocks to shake and bump around. The more quickly the box is shaken, the higher the temperature that is simulated.

5. Why do the models not self-assemble right away?
   Nature uses a combination of a number of weak bonds working together, rather than one strong one. One bond is not strong enough to withstand the shaking. The environment for self-assembly is also critical and must be just right. For instance, a temperature that is too high (too much shaking of the box) may cause the bonds to break.

FORMATIVE ASSESSMENT

Student will use the Student Learning Targets: Self-Assembly Student Sheet (see page 9), completing it as they go through the design and presentation of their self-assembly models.

STUDENT SHEET

Self-Assembly Challenge

Work in groups of three to meet the following challenge:

Your task is to design and build a three-dimensional, self-assembling model with two, three, four or more pieces that come together in a particular way—like jigsaw puzzle pieces. Use your knowledge of intermolecular forces and non-covalent bonds to build your model out of LEGO® blocks, small magnets, and superglue. The pieces need to be designed and constructed in such a way that they fit together in one, and only one, unique configuration.

Start designing using paper cut-outs. You will need to test your model and redesign the pieces until they work, using the Learning Targets Student Sheet to document your progress through the process.

Please show your model to the class, including at least the following in your presentation:

1. an explanation of the self-assembly process
2. a discussion of why your model did or did not work
3. a description of how weak bonds and geometric compatibility figure into your design

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SELF-ASSEMBLY PLANNING SHEET

USE THIS SHEET TO DOCUMENT YOUR DESIGN PROCESS.	
DESIGN #1 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #2 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #3 ☐ worked ☐ didn't work	**MODIFICATIONS:**

USE THIS SHEET TO DOCUMENT YOUR DESIGN PROCESS.

DESIGN #4 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #5 ☐ worked ☐ didn't work	**MODIFICATIONS:**
DESIGN #6 ☐ worked ☐ didn't work	**MODIFICATIONS:**

STUDENT LEARNING TARGETS
Self-Assembly

CHECK OFF	OUR GROUP CAN:	WE DID THESE ACTIVITIES:	EVIDENCE:
	Develop shapes capable of self-assembly.	We discussed: _______(shape) and _______ (shape) before agreeing on:	
	Identify the role of building block shape in self-assembly.	We identified the following functions:	
	Explain the intermolecular forces that contribute to the self-assembly process.	We diagrammed or built paper models of the building blocks. We identified the forces from analyzing our diagrams or models.	
	Use combinations of techniques to cause the models to self-assemble.	We listed the bonding forces for each compound in our exotic life form.	
	Achieve a 5% success rate in getting our models to self-assemble.	We did _________trials and _________ were successful.	
	Include other concepts in our models.	Our additional concepts were:	

NOTES:

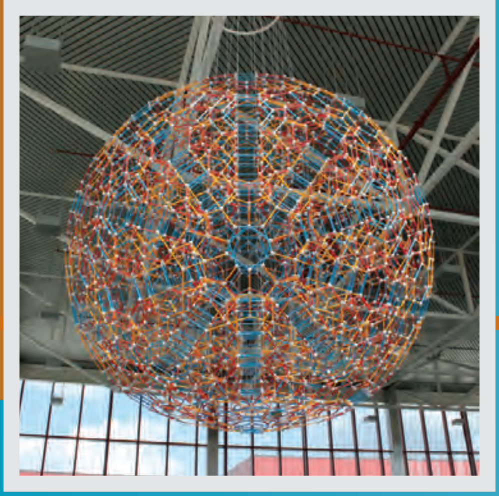
WHAT YOU'LL FIND HERE

- a "pick-up-and-go" lesson plan that will add science currency to your science program
- activities that meet science curriculum learning outcomes
- interesting subject matter that is engaging to teach
- easy to implement experiments (no specialized training needed)
- a quickly adaptable lesson with worksheets and rubrics for your class needs

Nano is... the scientific term meaning one-billionth (1/1,000,000,000). It comes from the Greek word meaning "dwarf".

Nano Science is... the discovery, research and understanding of all things nano.

Nanotechnology is... the application of science at the molecular level.

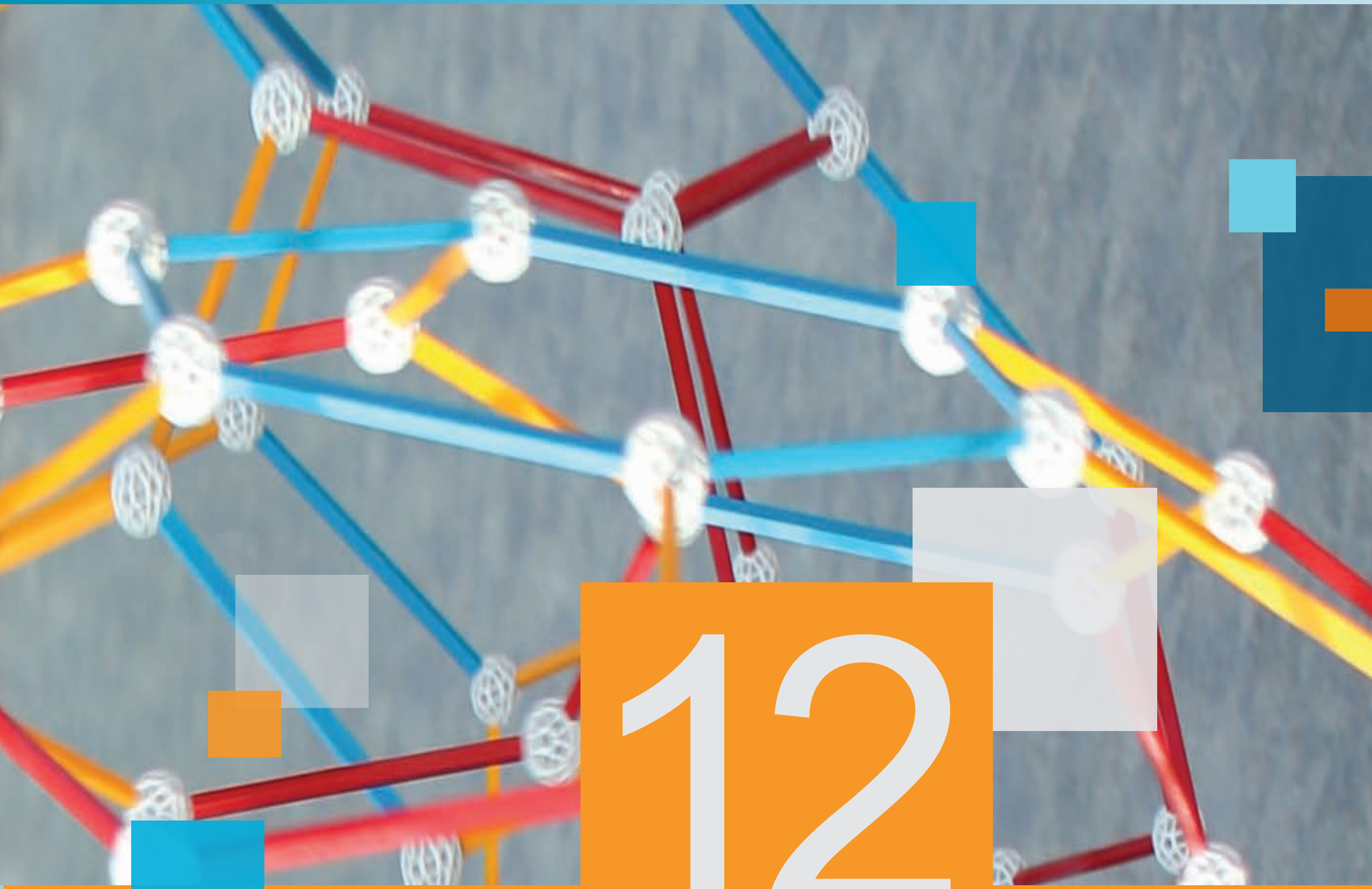


Nanotechnology is revolutionizing medicine, energy production, environmental protection, bioindustries and more!

Government of Alberta

NANOTECHNOLOGY

LESSON PLAN FOR BIOLOGY 30 - MEDICAL APPLICATIONS



12

Alberta

Freedom To Create. Spirit To Achieve.

Alberta Innovates Technology Futures

Science Teachers,

This lesson plan was designed for Biology 30 and meets Alberta Education curriculum learning outcomes for science (see the following page for program of studies reference). The plans are easy to understand and implement without any specialized training, additional work or study. Best of all, they make this interesting subject matter engaging to teach.

The lesson plans were focus tested in seven schools throughout Alberta, incorporating teacher's feedback, and received great reviews. These plans provide the tools necessary to guide students through interactive experiences with nanotechnology that will help them understand this aspect of science. Included in the lesson plans are:

- a short explanation on what is nanotechnology,
- an activity description,
- time requirements,
- materials,
- an assessment rubric, and
- an in-depth teacher's background for reference.

Did You Know?

The University of Alberta, the University of Calgary, and the Northern Alberta Institute of Technology all offer nanotechnology programs to train the next generation of curious and bright minds.

Each lesson was designed in a way that allows you to quickly adapt it to your specific class needs and/or level of knowledge. If you wish to go deeper into the material, you can use the links provided under References or Bibliography. These lesson plans are complemented by a Nano Resource DVD for additional resources such as comic strips, videos, photos and more information related to teaching and understanding nanotechnology. These resources are also available for downloading at **nanolessonplans.alberta.ca**.

As you can see, the subject of nanotechnology is rich with opportunities for learning. We hope you will find the lesson plans worth implementing and include this fascinating area of science in your science program for the year.

If you require more information on additional nanotechnology learning experiences, or have any questions about the information provided, please contact nanoAlberta at 780-450-5111 or email nano@albertainnovates.ca. For grades 7 to 12 check out our travelling Scanning Electron Microscope (SEM) program and book it for your school today. This free program supplies the Microscope for a week and an Alberta certified science teacher will come and work with you and your class or school. A great complement to the nano lesson plans.
Visit **nanolessonplans.alberta.ca** for more information on the SEM program.

ISBN 978-0-7785-9677-6 (print)
ISBN 978-0-7785-9678-3 (online)

1. Lesson planning – Alberta – Outlines, syllabi, etc.
2. Nanotechnology – Alberta –Curricula. I. Alberta. Alberta Advanced Education and Technology. II. Alberta Innovates –Technology Futures.

LB1027.4 N186 2011 371.3028

These lesson plans are available to view online and can be downloaded free at **nanolessonplans.alberta.ca**

Limited additional copies are available for ordering from the Learning Resource Centre at **lrc.education.gov.ab.ca**

For information, including reproduction for commercial purposes, please contact:
Alberta Innovates - Technology Futures
nanoAlberta
Phone: 780-450-5111
Email: nano@albertainnovates.ca

Program of Studies Reference:

Biology 30 - Cell Division, Genetics, and Molecular Biology

STS - 30 - C3.2

- Students will explain that scientific research and technological development help achieve a sustainable society, economy, and environment
  - Explore the application of nanotechnology and its implications for clinical diagnostics, pharmacology, biological research or proteomic programs.

Check out these other great Nanotechnology Lesson Plans

Nanotechnology: Lesson Plan for Grade 4 Science
Slippery Leaves

Nanotechnology: Lesson Plan for Grade 5 Science
Small is Different–Classroom Chemistry

Nanotechnology: Lesson Plan for Grade 6 Science
Forestry Nano Superheroes–Trees and Forests

Nanotechnology: Lesson Plan for Grade 7 Science
Nanotechnology and the Environment – Smart Dust

Nanotechnology: Lesson Plan for Grade 8 Science
Nanovision–Light and Optical Systems

Nanotechnology: Lesson Plan for Grade 9 Science
Carbon's Nanocaper–Matter and Chemical Change

Nanotechnology: Lesson Plan for Science 10
"BRANE" Work–Cycling of Matter in Living Systems

Nanotechnology: Lesson Plan for Chemistry 20
Putting it Together-Self Assembly
–The Diversity of Matter and Chemical Bonding

Did You Know?

Nanotechnology opens students to a wide variety of occupations in an even wider variety of industry sectors. Consider that nanotechnology may be encountered and used in some way by:

- Applications Technician
- Bio Material Engineer
- Cancer Researcher
- Characterization Scientist
- Chemical Technologist/Engineer
- Chemist
- Coating Scientist
- Computational Physicist
- Contact Metallization Process Engineer
- Electron Microscopy Technician
- Materials/Nanotechnology Scientist
- Materials/Metallurgical Engineer
- Mechanical Engineering
- Molecular Biologist
- Molecular Imaging Technologists
- Nanobiologist
- Nanoparticle Development Scientist
- Nanotechnology Business Manager
- Nanotechnology Laboratory Technician
- Nanotoxicologist
- Optical Engineer
- Pharmacologist
- Process Quality Engineer
- Product Marketing Manager
- Tissue Engineer
- Wafer Fabrication Development/Process Engineer

GRADE 12 MEDICAL APPLICATIONS OF NANOTECHNOLOGY

ACTIVITY DESCRIPTION

This lesson has 3 sections:

Part 1: Students take part in a simulation demonstrating how quantum dots are used in cancer diagnosis.

Part 2: Introduction to nanotechnology.

Part 3: In groups of four, students research a number of medical applications of nanotechnology, presenting their findings in the Pecha Kucha format (see Pecha Kucha fact sheet). Students can also include information about scientists in Alberta working on the application they've chosen to investigate.

TIME REQUIRED

Part 1: This demonstration should take about 30 minutes with the quantum dot information.

Part 2: 15 minutes.

Part 3: One class period to introduce the research project and begin research, and one period to present findings.
Each group will need 6 minutes 40 seconds for their presentation.

MATERIALS: for Simulation

- UV beads
- paper clamps
- sunlight or a UV light

Teacher background -
Quantum Dots (QD) for medical diagnosis

Adapted from the following sources:

Review of Quantum Dot Technologies for Cancer Detection and Treatment
www.azonano.com/Details.asp?ArticleID=1726

Multicolor quantum dots aid in cancer biopsy diagnosis.
http://www.sciencedaily.com/releases/2010/07/100706150624.htm

GLOSSARY
- microfluidics
- laminar flow
- quantum dots

WHAT ARE QUANTUM DOTS (QD)?

- Inorganic semiconductor nanocrystals 2-8 nanometres (nm) in diameter
- They have unique luminescent properties
- Wavelength of light emitted depends on the particle size
- Usually built of atoms from the II and VI elements (e.g. CdSe and CdTe) or groups III and V elements (e.g. InP and InAs) of the periodic table
- Can be used to track single receptor molecules on the surface of living cells in the body

HOW DO THEY WORK?

- For early diagnosis of cancer, the QD are chemically linked to antibodies which bind to molecules present on the surface or inside of cancer cells.
- Structure consists of:
  - a semiconductor core
  - an additional shell of ZnS to provide chemical and optical stability to the inner core
  - a water-soluble hydrophilic coating
  - functionalized antibodies or other biomarkers complementary to the target cancer cells.
- These QDs are then subjected to UV light to reveal the location of the cancer cells.

CLASS PREPARATION

Introduction to Nanotechnology

15 minutes

1. Show the following video:
   www.nanowerk.com/nanotechnology/videos/Kavli_Foundation_Introduction_to_Nanoscience.php

2. This PowerPoint presentation from the following NanoSense.org lesson plan can also be used: http://nanosense.org/activities/sizematters/index.html

PART 1: Quantum Dot Simulation

(This simulation is based on an idea proposed by John Griffiths of Harry Collinge High School, Hinton, Alta. Used with permission.)

In this simulation, the teacher is the diagnostician who distributes "antibodies" (the paper clamps) with quantum dots (UV beads) attached. Students are the cells to which the antibodies attach. You present information about what quantum dots are and how they are used to tag malignant cells. When students go outside (or when you shine a UV light on their "antibodies"), the beads will change colour. The UV light from the sun will cause the white beads to change colour, revealing the "code" or sequence of colours. Students will take note of their colour sequence and compare it to a key when they return to the classroom.

PART 2: Medical applications research

Students will continue to work in their groups of four to conduct the research and prepare their Pecha Kucha presentations. Show a sample Pecha Kucha so that students can get a feel for the format. Many are available here: www.pecha-kucha.org/presentations/. Students then choose a topic from the list below or do some browsing to find other medical applications. Another refreshing alternative presentation format to PowerPoint is Prezi (found at www.prezi.com).

Students might also include some slides that showcase an Alberta researcher working in the student's chosen area. The scientists might agree to a short interview to talk about their work. The chart on page 6 includes several of these researchers and their institutions.

Medical Applications List

Here are some samples of nanotechnology applications in medicine. Nanotechnology Now (www.nanotech-now.com) is a very good source of new releases about nanotechnology breakthroughs. It's written at a level that should be appropriate for Grade 12 students.

1. Pharmacology

a. Drug delivery systems: www.nanotech-now.com/news.cgi?story_id=28035
b. Drug smuggling cells: www.nanotech-now.com/news.cgi?story_id=39664

2. Clinical diagnostics

a. Alberta Research Lab on a Chip:
http://nextbigfuture.com/2010/04/radical-research-changes-lab-on-chip.html.
Contact information given in chart below.

b. Lab on a Chip: IBM Scientists Reinvent Medical Diagnostic Testing
www.nanotech-now.com/news.cgi?story_id=35439

c. Lab on a Chip: www.sciencedaily.com/releases/2010/02/100216113905.htm

d. Biosensors: Ultrasensitive Biosensor Can Detect Proteins, Aid in Cancer Diagnosis
www.nanotech-now.com/news.cgi?story_id=40127

3. Cancer treatment

a. Targeted delivery of chemotherapy drugs: www.youtube.com/watch?v=RBjWwlnq3cA

4. Bone grafts and implants

a. www.nanotech-now.com/news.cgi?story_id=37617
b. www.nanowerk.com/spotlight/spotid=8030.php
c. www.understandingnano.com/nanocluster-protein-bone-growth.html

Alberta researchers working in medical applications of nanotechnology
(Source: Alberta's Nanotechnology Asset Map)
Download here: http://www.albertatechfutures.ca/nanoAlberta/AlbertaNanoAssetMap.aspx

Researcher	Research Area
Colin Dalton University of Alberta Electrical & Computer Engineering	glucose sensor, lab on a chip, microneedles
Anastasia Elias University of Alberta Chemical & Materials Engineering	microfluidic devices, biomedical devices
Michael Ellison University of Alberta Biochemistry National Institute for Nanotechnology	automated miniaturized biofab systems capable of assembling modular DNA components into chromosomes at speeds over 100 times faster than conventional methods
Michael James University of Alberta Medicine and Dentistry	Viral enzymes, antiviral compounds, drug development, antibiotic development against tuberculosis.
Todd Lowary University of Alberta Chemistry National Institute for Nanotechnology	Preparation of nanoparticles or devices coated with foreign blood group antigens, which may be implanted into newborns before the immune system is fully developed. If present during the maturation of the immune system, these implants will create tolerance to these antigens in an infant's immune system, which will help prevent organ rejection.
James McMullin University of Alberta Electrical & Computer Engineering National Institute for Nanotechnology	portable diagnostic systems
Sushanta Mitra University of Alberta Mechanical Engineering National Institute for Nanotechnology	**Biological Applications:** - integrated BioMEMS and NanoSensors (real-time heat shock protein 70 monitoring in whole organisms; vitamins in clinical samples; cardiac monitoring) - design, fabrication, and characterization of a micro-filter for point-of-care system
Hasan Uludag University of Alberta Chemical & Materials Engineering	bone regeneration, cancer therapy

ASSESSMENT

Rubrics can be effective if students participate in writing the rubric. At the grade 12 level, this is quite doable. Below are some performance areas that could be included:

1 *Content:*

a. description of the medical application
b. explanation of the science behind the application
c. implications of the technology for sustainability
d. presenter's ideas about future direction or possible application for the technology/application
e. inclusion of Alberta researcher profile

2 *Presentation:*

a. adherence to the "20 slides of 20 seconds" requirement of Pecha Kucha
b. use of images
c. knowledge of subject matter demonstrated by not relying on notes
d. creative use of the Pecha Kucha form

Three to four levels of performance should be developed, with suggestions from students about what the different levels of performance might look like.

Discuss with the students what the levels of performance will look like within each category, developing the criteria and levels together.

A sample rubric for PowerPoint presentations can be found at the following link:
www.surfturk.com/composition/powerpointrubric.html.

EXTENSIONS

The following activity is a simulation/model of how the microfluidic flow works in a Lab on a Chip (LOC).

Lab on a Chip (LOC)

LOCs are credit card-sized devices based on capillary action or microfluidics (the ability to manipulate tiny volumes of liquid). They are used for faster point-of-care diagnostic medical tests and require much smaller samples than traditional lab analyzers. The chips are silicon-based and work at the nanoscale. The chips use the principle of laminar flow to control the mixing of samples and reagents. Laminar flow allows individual streams of fluid to flow separately without a physical barrier between them. Mixing between the streams occurs only through diffusion, and reactions can occur at the interfaces.
(http://www.youtube.com/watch?v=1_H2ZEsV8Rs)

This article explains a lot of the mechanics of lab on a chip: http://pubs.acs.org/doi/pdf/10.1021/ac002800y. This is large file, so it may download slowly—be patient. The second 'Y' channel Jell-O chip demonstrates laminar flow for students.

One possible application of LOC technology is for diagnosing heart attacks. The protein myoglobin floods the circulatory system during the minutes before a heart attack. Patients at risk might be issued a handheld device to test their own blood for elevated myoglobin levels. A patient who feels ill could test their own blood with a simple pinprick and then call for help if elevated levels were detected. This would help them get treatment much faster if a heart attack does occur.
(http://nextbigfuture.com/2010/04/radical-research-changes-lab-on-chip.html)

Lab on a Chip is just one of the medical applications of nanotechnology that students might research. There are a great number of others. The web links noted below will provide some basic information on the technologies for teachers as well as students. The NSTA (National Science Teacher Association) Learning Center has published a very good book called The Big ideas in Nanoscale Science and Engineering (Shawn Y. Stevens, LeeAnn M. Sutherland, Joseph S. Krajcik. Arlington, VA: NSTA Press. 2009. ISBN: 9781935155072), which is an excellent resource for teachers wanting to learn more about nanoscale science and its applications.

JELL-O CHIP FABRICATION

One class period (55 minutes), plus time for cells to cure.
Best done on a Friday so they can cure over the weekend.

The protocol is detailed in Appendix A and is used with permission of the principal investigator:

Dr. Eric Lagally
Michael Smith Laboratories & Department of Chemical
and Biological Engineering
#301 - 2185 East Mall
University of British Columbia
Vancouver, BC
V6T 1Z4

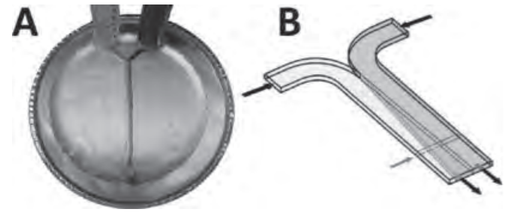
Source: Using Inexpensive Jell-O Chips for Hands-On Microfluidics Education
http://pubs.acs.org/doi/abs/10.1021/ac902926x

Detailed Protocol: See Appendix A

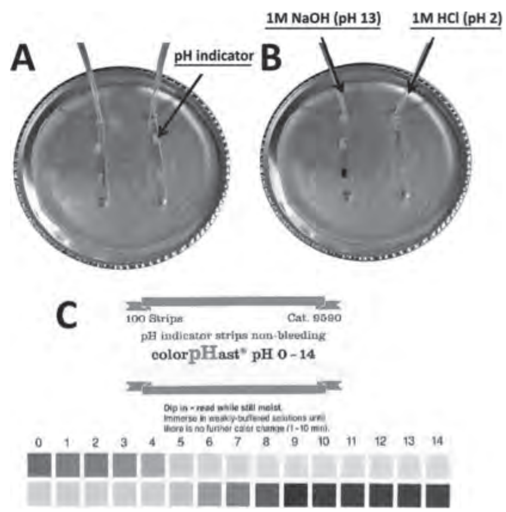
There are three possible chips that students can make. Teachers should choose the one best-suited to their curricular objectives. The options are:

One with a channel that spells out Jello-O:

One that demonstrates laminar flow:



One that demonstrates a pH application:



RESOURCES

Sargent, Ted. The Dance of the Molecules: How Nanotechnology is Changing Our Lives. This is a good source of information on the possibilities of nanotechnology. (ISBN-10: 1560258098, ISBN-13: 978-1560258094)

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2. "Multicolor Quantum Dots Aid in Cancer Biopsy Diagnosis." *ScienceDaily.* 7 July 2010. Web. 16 April 2011.
http://www.sciencedaily.com/releases/2010/07/100706150624.htm

3. Kavli Foundation: Introduction to Nanoscience." *KavliFoundation.* YouTube. 6 March 2008. Online Video. 16 April 2011.
http://www.nanowerk.com/nanotechnology/videos/Kavli_Foundation_Introduction_to_Nanoscience.php

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http://pubs.acs.org/doi/abs/10.1021/ac902926x

10. Sargent, Ted. *The Dance of the Molecules: How Nanotechnology is Changing Our Lives.* New York: Basic Books, 2006.

STUDENT SHEET

Medical Applications of Nanotechnology:

Your task is to research a medical application of nanotechnology with particular emphasis on work being done by Alberta researchers. Some suggestions for topics and preliminary information sources are listed below:

1. *Pharmacology*
   a. Drug delivery systems: www.nanotech-now.com/news.cgi?story_id=28035
   b. Drug smuggling cells: www.nanotech-now.com/news.cgi?story_id=39664

2. *Clinical diagnostics*
   a. Alberta Research Lab on a Chip:
      http://nextbigfuture.com/2010/04/radical-research-changes-lab-on-chip.html.
      Contact information given later in a chart.

   b. Lab on a Chip: IBM Scientists Reinvent Medical Diagnostic Testing
      www.nanotech-now.com/news.cgi?story_id=35439

   c. Lab on a Chip: www.sciencedaily.com/releases/2010/02/100216113905.htm

   d. Biosensors: Ultrasensitive Biosensor Can Detect Proteins, Aid in Cancer Diagnosis
      www.nanotech-now.com/news.cgi?story_id=40127

3. *Cancer treatment*
   a. Targeted delivery of chemotherapy drugs: www.youtube.com/watch?v=RBjWwlnq3cA

4. *Bone grafts and implants*
   a. www.nanotech-now.com/news.cgi?story_id=37617
   b. www.nanowerk.com/spotlight/spotid=8030.php
   c. www.understandingnano.com/nanocluster-protein-bone-growth.html

Please include:

- Description of the technology and what it does. What area—clinical diagnostics, pharmacology, biological research, or proteomic programs?
- Explanation of the nanoscience behind the application.
- Discussion of implications for sustainability.
- What stage is the technology—research and development, patent protection, pre-clinical trials, clinical trials, Health Canada's review process? See the following brochure below for details: www.pharmacists.ca/content/hcp/resource_centre/drug_therapeutic_info/pdf/DrugApprovalProcess.pdf
- One or two slides highlighting an Alberta researcher connected to your chosen application.

Your research will be presented in the Pecha Kucha style, which shows 20 slides for 20 seconds each (set on automatic advance). You might also use Prezi to present your research to the class.

STUDENT SHEET

Pecha Kucha Basics

Pecha Kucha, pronounced "peh cha' chkuh", is the Japanese word for "chatter".

- specific PowerPoint format using 20 slides each lasting exactly 20 seconds
- slides are set to change automatically
- total presentation time is 6 minutes 40 seconds
- description of Pecha Kucha: www.youtube.com/watch?v=wGaCLWaZLI4
- Daniel Pink on Pecha Kucha: www.youtube.com/watch?v=9NZOt6BkhUg

Examples

Clowns Without Borders: www.pecha-kucha.org/presentations/195
PangeaSeed - Save the Ocean: www.pecha-kucha.org/presentations/204
Picture books: www.pecha-kucha.org/presentations/170

Alternative presentation method: Prezi

Prezi is free interactive online presentation software that can provide a refreshing alternative to PowerPoint. You can find it at http://prezi.com.

STUDENT SHEET

Alberta researchers working in medical applications of nanotechnology

Below is a chart showing a number of Alberta researchers who are working on different medical applications of nanotechnology.

Researcher	Research Area
Colin Dalton University of Alberta Electrical & Computer Engineering	glucose sensor, lab on a chip, microneedles
Anastasia Elias University of Alberta Chemical & Materials Engineering	microfluidic devices, biomedical devices
Michael Ellison University of Alberta Biochemistry National Institute for Nanotechnology	automated miniaturized biofab systems capable of assembling modular DNA components into chromosomes at speeds over 100 times faster than conventional methods
Michael James University of Alberta Medicine and Dentistry	Viral enzymes, antiviral compounds, drug development, antibiotic development against tuberculosis.
Todd Lowary University of Alberta Chemistry National Institute for Nanotechnology	Preparation of nanoparticles or devices coated with foreign blood group antigens, which may be implanted into newborns before the immune system is fully developed. If present during the maturation of the immune system, these implants will create tolerance to these antigens in an infant's immune system, which will help prevent organ rejection.
James McMullin University of Alberta Electrical & Computer Engineering National Institute for Nanotechnology	portable diagnostic systems
Sushanta Mitra University of Alberta Mechanical Engineering National Institute for Nanotechnology	**Biological Applications:** - integrated BioMEMS and NanoSensors (real-time heat shock protein 70 monitoring in whole organisms; vitamins in clinical samples; cardiac monitoring) - design, fabrication, and characterization of a micro-filter for point-of-care system
Hasan Uludag University of Alberta Chemical & Materials Engineering	bone regeneration, cancer therapy

Source: Alberta's Nanotechnology Asset Map (download here) :
http://www.albertatechfutures.ca/nanoAlberta/AlbertaNanoAssetMap.aspx

APPENDIX A:

SUPPORTING INFORMATION

(Used with permission of Dr. Eric Lagally)

Detailed Chip Fabrication Protocol

List of Materials Required for Jell-O® Chip Fabrication

- Two 85g boxes of lemon-flavored Jell-O® jelly powder (Kraft Canada)
- One pouch (7g) of unflavoured (the Original) Knox Gelatine (Associated Brands LP)
- 2 beakers of 120mL of purified water for dissolving Jell-O® and Knox Gelatine
- Six 6” foam plates, round (Safeway Limited Canada)
- One drinking straw, round (Safeway Limited Canada)
- PAM® Original no-stick cooking spray (ConAgra Foods Canada Inc.)
- Several 7” wooden coffee stirrers (Starbucks Coffee Company Canada)
- Food-grade colour dye, green (McCormick Canada)
- Single- and double-sided tape (3M Canada)
- Six 5” aluminum weighing pan (Cat No. 12175-001, VWR International)

Sources of Chemicals and Materials

Lemon-flavored Jell-O® Jelly Powder, unflavoured gelatin, round foam plates (6”), drinking straws, no-stick cooking spray, wooden coffee stirrers (7”), food-grade colour dyes, and single- and double-sided tape were obtained from local convenience stores. Aluminum weighing pans (5”), 10 mL syringes and Disposable Transfer Pipets were purchased from VWR International. ColorpHast Indicator Strips (pH 0-14) were acquired from EM-Reagents. Sodium Hydroxide (NaOH) and Hydrochloric Acid (HCl, 37% A.C.S. reagent) were obtained from Sigma. All solutions were prepared using ~18.2 M-cm water treated with a water purification system (Barnstead EASYpure® II Ultrapure).

Jell-O® Chip Fabrication

Initially, the molds with desired features were made using foam plates, coffee stirrers and double-sided tape. To make the chips, two pouches of Jell-O® jelly powder were dissolved in 120 mL of purified water in a beaker. One pouch of Knox Gelatine powder was dissolved in the same amount of water in a second beaker. The beaker containing the Jell-O® solution was placed on a hot plate and heated to a boil. This beaker was removed from the heat and the gelatin solution was added to it. The mixture of Jell-O® and gelatin solution was again heated to a boil and removed from the heat. Prior to pouring the mixture of Jell-O® and gelatin solution into the mold, cooking spray was dabbed onto the inside rim of the foam plate to facilitate the peeling process after curing.

The mixture solution was poured into six molds and they were transferred to a 4°C refrigerator for curing. Curing the chips overnight was usually sufficient; however, curing for at least two days in the refrigerator resulted in more robust Jell-O® chips. After curing, Jell-O® chips were carefully peeled off and placed on aluminum pans for experimental demonstrations. Lemon-flavored Jell-O® jelly powder was used because it produced chips with the best optical transparency. Inlet and outlet holes were punctured using a drinking straw. In all of the chips produced, the natural and reversible seal between the Jell-O® chip and the aluminum pan was adequate for the flow rates that were encountered. Lawson and Abbot, both high school students in Vancouver, BC, fabricated the chips and conducted the initial experiments presented here, demonstrating the accessibility of this technology to students at this educational level.

Module I: Pressure-driven flow

Materials Required:

- One Jell-O® microfluidic chip with a continuous channel depicting the letters "JELLO" (see Supporting Information regarding detailed chip fabrication protocol)
- One 5" aluminum pan (Cat No. 12175-001, VWR International)
- One disposable transfer pipet (Cat No. 16001-178, VWR International)
- A small vial of water with a few drops of green food coloring dye (~30mL)

Mold Fabrication Guide:

The coffee stirrers were cut into rectangular shapes of various lengths. They were then taped onto the foam plate, forming the letters "JELLO", using double-sided tape. Single-sided tape was taped at junctions of coffee stirrers to ensure a smooth overall mold surface.

Additional Tips:

The Jell-O® chips should be stored in the 4°C refrigerator until immediately prior to peeling the chips and running the experiments. Thicker chips can be made by reducing the number of molds made (to three or four). However, increasing the thickness of the chips will most likely affect and lengthen the curing time. From experience, a ratio of 4 people per chip is adequate for these demonstrations.

Module II: Dimensionless parameters

Materials Required:

- One Jell-O® microfluidic chip with a Y-shaped channel
- One 5" aluminum pan (Cat No. 12175-001, VWR International)
- Two disposable BD 10mL syringes (Product No. 309604, BD Canada)
- A small vial of water (~30mL)
- A small vial of water with a few drops of blue food coloring dye (~30mL)

Mold Fabrication Guide:

Two pieces of coffee stirrers were required for forming the Y-channel mold. A long rectangular-shaped coffee stirrer was first obtained (~3 inches long) by trimming the first coffee stirrer at both ends. One end of this coffee stick should be flat (outlet) and the other end should be dagger-shaped. The second coffee stirrer can be cut into two smaller rectangular-shaped sticks of the same length (~1 inch long). The longer coffee stirrer was taped near the middle of the foam plate using double-sided tape. The two smaller sticks were similarly taped at the dagger-shaped end of the longer stick, forming a mold with the letter "Y". Single-sided tape was taped at the junction of three coffee stirrers to ensure a smooth mold surface.

Additional Tips:

To prevent leaking from the inlets, the syringes should be perfectly perpendicular with the surface, and the head of the syringes should completely seal the inlets. Both clear and green water should be injected slowly but evenly into the channels, in order to create the laminar flow profile. The most common problem we encountered with the Y-Channel chip was with peeling the chip off of the mold, especially at the junction of the three coffee stirrers. Patience, care, and experience will help with the peeling process. If Y-Channel chips are too difficult to make, simple T-Channel chips can also produce the same results. Two rectangular-shaped coffee stirrers can be combined to make the letter "T" on a foam plate. Two inlet holes and one outlet hole should still be punctured as before. Laminar flow profile can still be seen with the T-Channel chips.

Module III: Fundamentals of pH Sensing & Parallelization

Materials Required:

- One Jell-O® microfluidic chip with two straight channels
- One 5" aluminum pan (Cat No. 12175-001, VWR International)
- Two disposable transfer pipets (Cat No. 16001-178, VWR International)
- Two small pieces of acid-sensing pH paper (Cat No. 9590, EM Science)
- Two small pieces of base-sensing pH paper (Cat No. 9590, EM Science)
- A small vial of 1M hydrochloric acid (258148, Sigma-Aldrich) (or cooking vinegar)
- A small vial of 1M sodium hydroxide (S8045, Sigma-Aldrich) (or dissolved antacid solution)

Mold Fabrication Guide:

Two pieces of coffee stirrers were required for forming the pH Sensor mold. Two long rectangular-shaped coffee stirrers of the same length were obtained (~2.5 inches long). These sticks were then taped onto the foam plate using double-sided tape, at ~1 inch apart.

Additional Tips:

Extreme caution should be taken when working with one-molar NaOH and HCl. Constant supervision is required, and this step is not suitable for younger students. Household solutions that are milder may be used instead of HCl and NaOH. Common acidic solutions include vinegar and lemon juice; common basic solutions include dissolved antacid solutions and soapy water.

Further Information and Videos

Further information about the most effective teaching methods for this material and to see videos of the chips in operation, please see:
http://www.msl.ubc.ca/training/outreach

NOTES:

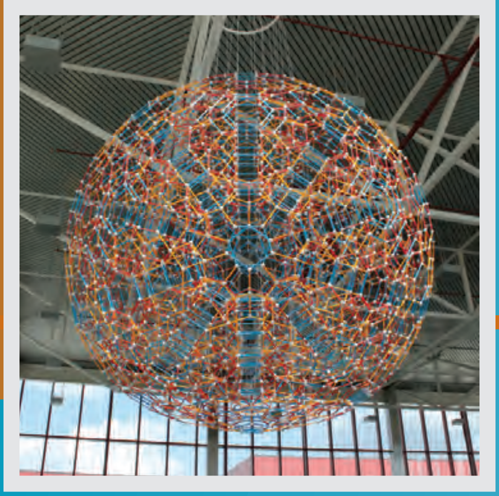
WHAT YOU'LL FIND HERE

- a "pick-up-and-go" lesson plan that will add science currency to your science program
- activities that meet science curriculum learning outcomes
- interesting subject matter that is engaging to teach
- easy to implement experiments (no specialized training needed)
- a quickly adaptable lesson with worksheets and rubrics for your class needs

Nano is... the scientific term meaning one-billionth (1/1,000,000,000). It comes from the Greek word meaning "dwarf".

Nano Science is... the discovery, research and understanding of all things nano.

Nanotechnology is... the application of science at the molecular level.



Nanotechnology is revolutionizing medicine, energy production, environmental protection, bioindustries and more!

Government of Alberta

NANO RESOURCES DVD

This DVD offers resources such as videos, nano photos, comic strips and more that will help support implementation and complement the lesson plans.

Visit **nanolessonplans.alberta.ca** for downloadable resources and updated materials.

WHAT YOU'LL FIND HERE

- three "pick-up-and-go" lesson plans that will add science currency to your science program
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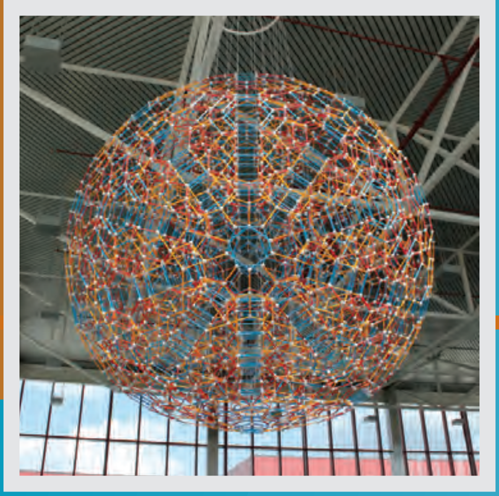

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