

**December 2016/January 2017 Teacher's Guide for**

***Preserving Organs: Saving Lives, Giving Hope***

**Table of Contents**

[About the Guide 2](#_Toc468102646)

[Student Questions 3](#_Toc468102647)

[Answers to Student Questions 5](#_Toc468102648)

[Anticipation Guide 7](#_Toc468102649)

[Reading Strategies 8](#_Toc468102650)

[Connections to Chemistry Concepts 11](#_Toc468102651)

[Possible Student Misconceptions 11](#_Toc468102652)

[Anticipating Student Questions 11](#_Toc468102653)

[Activities 12](#_Toc468102654)

[References 14](#_Toc468102655)

[Web Sites for Additional Information 14](#_Toc468102656)

# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

# Student Questions

**Preserving Organs: Saving Lives, Giving Hope**

* 1. Define osteosarcoma.
  2. What is a complication of the anticancer drug called doxorubicin?
  3. Describe two reasons why organ donor candidates may not receive a new organ.
  4. What is the average number of human organs transplanted each day in the United States?
  5. On average, how many people who die each day because they don’t receive a donor organ?
  6. What two factors determine the preservation time limit of a donor heart?
  7. Organs cannot be frozen successfully, due to the expansion of ice as water freezes. Use hydrogen bonding to explain why this expansion occurs.
  8. What effect do newly formed ice crystals have on red blood cells?
  9. How do cryoprotectants prevent ice crystal formation?
  10. Describe how scientists have been able to supercool organs removed from test animals.
  11. Describe the process of vitrification.
  12. List two things that happen to the molecules within an organ that has been vitrified to temperatures below –100 °C.

# Answers to Student Questions

**(taken from the article)**

**Preserving Organs: Saving Lives, Giving Hope**

1. **Define osteosarcoma.**

*Osteosarcoma is a cancerous bone tumor.*

1. **What is a complication of the anticancer drug called doxorubicin?**

*Doxorubicin cardiomyopathy is a rare complication of doxorubicin.*

1. **Describe two reasons why organ donor candidates may not receive a new organ.**

*The two reasons candidates may or may not get a transplant are:*

1. *A supply issue is one reason. There are fewer donor organs available than the number of people who need them. Also, to prevent rejection, a donor organ must be a good match for the recipient’s immune system.*
2. *The second reason why an organ donor candidate may not receive a new organ relates to logistics. A donor organ such as a heart only remains healthy for about 4 hours, so it cannot be too far away from the donor recipient.*
3. **What is the average number of human organs transplanted each day in the United States?**

*On average, 79 organs are transplanted daily in the U.S.*

1. **On average, how many people who die each day because they don’t receive a donor organ?**

*The average number of people who die each day because they never received an organ is 22.*

1. **What two factors determine the preservation time limit of a donor heart?**

*Preservation time limit is the result of both the temperature and the composition of the solution.*

1. **Organs cannot be frozen successfully, due to the expansion of ice as water freezes. Use hydrogen bonding to explain why this expansion occurs.**

*Hydrogen bonds between water molecules are constantly forming and breaking at higher temperatures. As the temperature drops and ice crystals form, the hydrogen bonds between the water molecules at 0 °C form a “hexagonal crystal lattice structure”, where the molecules are held rigidly in place. This produces large gaps between molecules and lots of open space. The diagram shows that water molecules at 10 °C can pack together rather tightly between the continuously moving water molecules.*

1. **What effect do newly formed ice crystals have on red blood cells?**

*Newly formed ice crystals push on the membranes that surround the red blood cells, causing damage to the cells.*

1. **How do cryoprotectants prevent ice crystal formation?**

*Cryoprotectants get into the cytoplasm of cells, which is mostly water, and act as antifreeze. They prevent ice crystal formation by lowering the freezing point. The liquid outside the cells also has a lower freezing point. This is due to the ions in solution as well as the cryoprotectants.*

1. **Describe how scientists have been able to supercool organs removed from test animals.**

*Scientists use equipment similar to a cardiopulmonary bypass machine. It pumps fluid through the organ’s blood vessels. The fluid contains cryoprotectants, which work their way into and around the cells and the organ is supercooled.*

1. **Describe the process of vitrification.**

*An organ full of cryoprotectants is cooled to very low temperatures (-100 °C). The water within the organ solidifies without forming crystals.*

1. **List two things that happen to the molecules within an organ that has been vitrified to temperatures below –100 °C.**

*When molecules are vitrified to temperatures below* –*100 °C molecules hardly move and they stop reacting with one another.*

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Potassium ions slow the metabolic rate of the heart. |
|  |  | 1. Ice crystals begin to form at temperatures below 4° C. |
|  |  | 1. Donor hearts are frozen prior to transplantation into a recipient. |
|  |  | 1. On average, more than 1000 organs are transplanted every day. |
|  |  | 1. Donated hearts can be preserved for a longer time than donated kidneys. |
|  |  | 1. Hydrogen bonding is responsible for the rigid hexagonal crystal lattice structure of ice. |
|  |  | 1. Adding cryoprotectants such as glycerol to red blood cells lowers the freezing point. |
|  |  | 1. Vitrification occurs when solids solidify without forming crystals. |
|  |  | 1. When molecules move more slowly, chemical reactions increase. |
|  |  | 1. Currently, donated human organs are banked the same way we bank blood for transfusions. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading and writing strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies:***

1. Links to **Common Core Standards for Reading**:

* ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
* ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
* ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
* ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

1. Links to **Common Core Standards for Writing**:

* ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
* ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.

1. **Vocabulary** and **concepts** that are reinforced in this issue:

* Chemical reactions
* Redox reactions
* Solubility
* Equilibrium
* Le Chatelier’s Principle
* Vitrification
* Hydrogen bonding
* Molecular structures
* Personal and community health
* Rare-earth metals
* Endothermic and exothermic reactions
* Conservation of energy

1. Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make informed choices as citizens and consumers.
2. Engagement suggestions:

* Prior to giving students the article “The Flint Water Crisis: What’s Really Going On?” use a Think-Pair-Share to find out what students already know about the Flint water crisis. During reading, students will reflect on what they thought and how the evidence from the article supports their original ideas (or not).
* Avoid telling students the title of the article, “No Smartphones, No TV, No Computers: Life without Rare-Earth Metals.” Instead, ask them where in their everyday lives they would find rare-earth metals and why they are used. After a short class discussion, give them the article to read.

1. To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teacher’s Guide has suggestions for further research and activities.

**Directions**: As you read the article, complete the graphic organizer below to describe how human organs are preserved for transplantation.

|  |  |
| --- | --- |
| **How are organs currently preserved?** | **Preserving Organs**  **Problems with freezing organs** |
| **Compare preserving organs to preserving blood cells and plasma.** | **Ideas for extended organ preservation in the future** |

**Summary**: On the back of this paper, write a one-sentence summary (20 words or less) of the article.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Reaction rate**—Using biological metabolic rates, this article provides a nice introduction for a discussion on how temperature affects rates of reaction.
2. **Solution concentration**—A discussion about perfusion solutions and cryoprotectants is a nice way to provide students with relationships between solution concentration and toxicity, as well as solution concentration and freezing point depression.
3. **Crystal formation**—The size of a crystal is related to the rate at which it forms. Crystals that are produced by quick freezing tend to be small and many, while crystals formed during slow temperature changes tend to be larger. The formation of smaller crystals cause less damage to living tissues. So the rate of temperature change during cooling and rewarming during cryopreservation is important.
4. **Hydrogen bonds**—Hydrogen bonding in water has a large impact on organ preservation. Hydrogen bonding causes the 3-dimensional network structure of water, and expansion of this 3-dimensional lattice of water molecules as they freeze can damage cells and organ tissue**.**
5. **Freezing point temperature**—The article discusses organs are preserved and maintained at just a few degrees above the freezing temperature of water.
6. **Colligative properties**—The article gives a practical application of colligative properties in cryopreservation and vitrification.
7. **Freezing point depression**—The article discusses how cryoprotectants contain glycerol and hydroxyethyl starch that both act as antifreezes that lower the freezing temperature.
8. **Supercooling**—The article explains how supercooling can be used to prevent ice crystals from forming and damaging living organs and cells
9. **Amorphous solids**—The process of vitrification forms amorphous solids. This article provides students with a biological example of an amorphous solid.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“After only two weeks, Jim is out of the hospital and ready to begin life with his new heart.”** *This statement makes it sound like recovery is quick and easy and Jim is out of the woods with health issues. Doctors will need to monitor his immune response to make sure that his body doesn’t reject his new heart and watch for side effects from the immunosupressants and steroids. Also, heart transplants usually only last for about 15 years for teenagers.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“Jim only had to wait for a donor heart for one week. My neighbor needed a kidney transplant and had to wait 2 years. What is the average wait time for a donor organ?”** *The United Network for Organ Sharing manages the wait list for organ recipients. The system was developed in response to the National Organ Transplant Act of 1984. There are 11 regions around the country and each is served by a local organ procurement organization. Patients are evaluated by transplant doctors in local transplant centers. The evaluation looks at medical urgency; blood, tissue, and size match; time on the list; and proximity to the donor. Special accommodations may be made for children. These are the median average wait times: Kidney—5 years, Liver—11 months, Heart—4 months, Lung—4 months, Kidney / Pancreas—1.5 years, Pancreas—2 years.*
2. **“When I was waiting in line at the DMV to get my driver’s license, there was a 70 year-old woman who had marked YES to be an organ donor. Isn’t she too old to donate an organ?”** *There is no age limit for organ donation. There have been 80 year-olds who have donated organs. And most health conditions don’t disqualify you from donating an organ. Qualified medical professionals evaluate organs at the time of death.*
3. **“There is a picture of a frozen kidney on page 11 of this issue of *ChemMatters*. Is that a human kidney at –140 °C? Didn’t the article state that human organs have not yet been frozen to temperatures that cold?”** *You are correct—whole human organs have not yet been frozen. Heart valves, vascular tissue, cartilage, and corneas have successfully been vitrified, but human organs have not. This is a picture of a rabbit kidney that was vitrified to* **–***140 °C, rewarmed and then successfully transplanted into a recipient rabbit, which survived.*

# Activities

**Labs and Demos**

1. **30-minute lab on cooling curve:** Students melt sodium thiosulfate crystals, and these are then cooled to a state well below the melting point. The supercooled liquid will freeze rapidly on the addition of a single crystal of sodium thiosulfate, or on stirring, which seeds the crystallization process. Temperature changes are observed throughout. (<http://www.rsc.org/learn-chemistry/resource/res00000390/supercooling-the-energetics-of-freezing?cmpid=CMP00005920>)
2. **How do different types of solutes affect the freezing of water?** Students design an investigation. They will need to think about what type of data to collect, how they will collect the data, and how they will analyze the data. The lab makes connections to NGSS Crosscutting concepts, the Nature of Science, and the Nature of Inquiry. (<https://www.nsta.org/publications/press/extras/files/adi-chem/Lab8StudentHandout-SolutesAndTheFreezingPointOfWater.pdf>)
3. **Demonstrate the behavior of supercooled water:** This site gives step-by-step directions for making supercooled water and then, “on command”, crystallizing it into ice.(<http://chemistry.about.com/od/chemistryhowtoguide/a/how-to-supercool-water.htm>)
4. **“Colligative Properties: Making Ice Cream Lab”:** Students will determine the freezing point depression of a brine solution used to freeze an ice cream mixture. ([www.georgetownisd.org%2Fcms%2Flib%2FTX01001838%2FCentricity%2FDomain%2F526%2FUnit%25209%2520Ice%2520Cream%2520Lab%25202012.doc&usg=AFQjCNHiG65npZxLHqGnSXgEy7VqOdOtaA&sig2=OhsqudU9D3O2D43A7oIfcg&cad=rja](https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwi6pdCX1tzPAhWMdj4KHeUyAuMQFgglMAE&url=http%3A%2F%2Fwww.georgetownisd.org%2Fcms%2Flib%2FTX01001838%2FCentricity%2FDomain%2F526%2FUnit%25209%2520Ice%2520Cream%2520Lab%25202012.doc&usg=AFQjCNHiG65npZxLHqGnSXgEy7VqOdOtaA&sig2=OhsqudU9D3O2D43A7oIfcg&cad=rja))
5. **Water lab and hydrogen bonds:** Students will observe what happens when they add drops of water to a penny. They will relate the property of surface tension to hydrogen bonding.

(<http://www.mlhi.org/school05/surface_tension_lab.doc>)

**Simulations**

1. **Explore colligative properties:** This simulation begins with an examination of vapor pressure. Students then explore how adding different solutes to a solvent changes its vapor pressure. Finally, students can use the third simulation to practice calculations involving boiling point elevation and freezing point depression.

**(**<http://www.chem.fsu.edu/chemlab/chm1046course/colligative>)

1. **Explore specific heat:** Using the PhET simulation “Energy Forms and Changes” students will describe heat flow from hot to cold and explore that some materials release more energy than others (specific heat).

(<https://phet.colorado.edu/en/contributions/view/4400>)

**Media**

1. **Heart transplant operations:** The video shows a heart transplantation. It begins with the harvesting of the donor heart (frequently at a remote site, as in the video). Another surgeon stays with the patient to prepare him for the transplant (opening the chest and installation of cardiopulmonary bypass). Coordination between the two surgical teams (logistics, transportation, anesthesia and incision) must be perfect in order to minimize the duration of ischemia. (<https://www.youtube.com/watch?v=_SDXsjM23_E>)

**Lessons and Lesson Plans**

* 1. **“Cooling Off”, designing a cooling system:** This lesson is developed using the 5E Model of learning. Working in teams, students conduct experiments relating to specific heat on a cooling system they design. They are then challenged to improve the cooling system. The National Standards addressed include science as inquiry, science and technology, measurement, data analysis, probability representation, critical thinking, problem solving, and decision making. (<http://www.nasa.gov/pdf/272501main_CoolingOff_508_916A.pdf>)

**Projects and Extension Activities**

1. **“Solubility Science: How to grow the best crystals”:** This can be done as a class contest to see which student can grow the largest crystal. In this activity, students will compare the size and shape of different crystals grown at different temperatures.

(<https://www.scientificamerican.com/article/bring-science-home-crystals/>)

# References

**(non-Web-based information sources)**

**The references below can be found on the *ChemMatters* 30-year DVD, which includes all articles   
published from the magazine’s inception in October 1983 through April 2013; all available Teacher’s Guides, beginning February 1990; and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab to the left, directly under the “*ChemMatters Online"* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen).**

**Selected articles and the complete set of   
Teacher’s Guides for all issues from the past three   
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMatters Online”*.**



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Supercooling is discussed in this article as it relates to the use of sodium acetate trihydrate in heat packs. (Marsella, G. Hot and Cold Packs. *ChemMatters*, 1987 *1* (4), pp 7–12)

This article describes how the shape of snowflakes are the result of two properties of water—its polarity and its shape. The article also describes the rough shape of an ice crystal. (Hazard, A. Science of Snowflakes. *ChemMatters*, 2009, *27* (4), pp 9–10)

Perhaps we won’t have to worry about preserving organs in the future; engineered organs may someday take the place of “natural” organs. This article discusses engineered organs. (Warner, J. Living with an Artificial Bladder. *ChemMatters*, 2013, *31* (1), pp 6–8)

# Web Sites for Additional Information

**(Web-based information sources)**

**Organ donors**

The United Network for Organ Sharing contains data on every organ donation and transplant that has occurred in the United States since 1987.

(<https://www.unos.org/data/transplant-trends>)

This article discusses how using organs from donors 65 years and older is now more common than in the past. This increases the number of available organs available for transplants.

(<http://www.nytimes.com/2016/08/16/health/organ-donor.html>)

**As more people die from drug overdose, their organs are saving the lives of individuals who would normally die waiting for a donor organ. In 2016, diseased drug users accounted for 12% of all donors in the United States. While drug users are considered high risk for diseases like HIV and hepatitis C, with new screening techniques, the risk of transplanting an infected organ is small.**

(<http://www.nytimes.com/2016/10/06/us/as-drug-deaths-soar-a-silver-lining-for-organ-transplant-patients.html>)

This article describes how the current practice for matching donor organs with recipients is inefficient and results in many organs ending up as medical waste or in research laboratories. Researchers project that a redesigned system could add 10,000 years of life from one year’s worth of donated organs. But, is it a fair system?

(<http://www.nytimes.com/2012/09/20/health/transplant-experts-blame-allocation-system-for-discarding-kidneys.html>)

A kidney donor discusses the imperfections in the idea of informed consent.

(<https://www.washingtonpost.com/national/health-science/at-18-years-old-he-donated-a-kidney-now-he-regrets-it/2016/09/30/cc9407d8-5ff9-11e6-8e45-477372e89d78_story.html>)

The U.S. transplant system forbids payment for organs; however, there is a severe shortage of donor kidneys, and some feel that the system should re-evaluate this ban with hopes of relieving the shortage. Researchers surveyed Americans about their willingness to become living kidney donors and how being compensated would affect their thinking. The results of the survey are discussed.

(<https://www.washingtonpost.com/news/to-your-health/wp/2016/03/23/what-would-happen-if-you-offered-to-pay-americans-to-donate-their-kidneys/?tid=a_inl>)

**Doxorubicin and anthrocycline antibiotics**

This booklet, which is published by the National Historic Chemical Landmarks Subcommittee of the American Chemical Society, describes the work done by Selman Waksman and his students to detect antimicrobial agents produced by microorganisms. The source will give insight into the deliberate search for chemotherapeutic agents.

(<https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/selmanwaksman.html>)

**Organ cryopreservation**

This site describes the procedure and advantages of cryopreservation. (<http://www.forbes.com/sites/paulrodgers/2014/06/30/transplant-breakthrough-donor-organs-stored-for-days/#4e7b8f9e1c30>)

The invention and patent application describes solutions and methods for preserving donor organs and storing them for extended periods of time before transplantation. (<https://www.google.ch/patents/US7029839>)

This article discusses some of the advances that are taking place in cryopreservation.

(<http://www.lifezette.com/healthzette/so-youd-like-to-freeze-your-kidneys/>)

Scientists are studying natural adaptation to cold by amphibians and fish to learn more about cryopreservation with the hopes for “freezing” human organs.

<http://www.the-scientist.com/?articles.view/articleNo/34190/title/Icing-Organs/>

**Perfusion**

This article gives a history of organ preservation and perfusion systems: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3088735/>.

**3-D organ printing**

This short video shows how 3-D printing is helping to revolutionize organ repair and rebuilding. (<https://www.youtube.com/watch?v=eZ6GQfXEmyM>)

This video shows some of the human tissue being produced by 3-D printers that could eventually replace real tissues. (<http://qz.com/616185/this-3d-printer-creates-human-muscles-and-tissues-that-could-actually-replace-real-ones/>)

**Synthetic organs**

To combat the problems of organ shortage and to decrease the chance that a patient’s body will reject it, researchers have been working to create synthetic organs from patients’ own cells. (<http://www.popsci.com/scientists-grow-transplantable-hearts-with-stem-cells>)