Program Guidebook

Science Undergraduate Laboratory Internship *(SULI)*

Community College Institute of Science and Technology *(CCI)*

Pre-Service Teachers *(PST)*

Faculty and Student Teams *(FaST)*

Office of Science

U.S. DEPARTMENT OF ENERGY

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Section A: Welcome and Valuable Information

Welcome

Congratulations on being selected as a research intern for the U. S. Department of Energy's (DOE) Office of Science (SC). The quality of your experience largely depends on you. If you take the initiative to learn all you can and positively contribute your thoughts, ideas, questions, and efforts to the research team you are working with, you will gain insight into how science is performed at your laboratory.

The purpose of this Program Guidebook is to assist you with the required deliverables of your research experience. Whether you are preparing an abstract of your research, a research paper, an oral presentation, an educational module, or a poster presentation, this guidebook will provide formatting requirements and examples to ensure that your research is presented in a consistent, professional manner. Your abstracts will be published in the DOE's *Journal of Undergraduate Research* (JUR) and it is important that you understand the formatting requirements for that publication. A selection of outstanding research papers will be published and those students will present their research at the American Association for the Advancement of Science (AAAS) annual meeting in mid-February.

Students may also elect to have their papers reviewed for publication in the *Journal of Young Investigators* (JYI). This is not a DOE-funded journal; it is a peer-reviewed publication for undergraduate research. More information about JYI is available at http://www.jyi.org. Your laboratory and DOE will conduct the first review of research papers from students who elect to have their papers reviewed for possible publication in the JUR. Papers not selected for publication in the JUR may be submitted to the JYI for their consideration.

The website that will serve as the center for program information and the place for submitting your required deliverables is called "educationLink" or "eduLink." The URL for this website is http://educationlink.labworks.org. To access the website, use the username and password that you created for your online application. If you are unsure of your username and password, you can request them by clicking on the link for "forgotten passwords." Some resources on the eduLink website are:

- Online lessons about security requirements, environmental awareness, safety regulations, and organizations that you need to know about as a DOE intern;
- A syllabus for the seminars, meetings, and tours that you may attend during your internship;
- Advice on submitting your required deliverables and a link to upload them;
- Links for surveys to provide feedback regarding your research experience;
- An electronic bulletin board to share ideas, concerns, and experiences; and
- Links for professional societies and job opportunities.

After you have completed your required deliverables, you will submit them to the DOE via the eduLink website. It is important to read this guidebook carefully to ensure that your required deliverables are in the proper format prior to submitting them. Your mentor and the education program staff at your laboratory will be available to assist you and to answer any questions that you may have regarding the format and content of your work.

U.S. Department of Energy
Office of Science
educationLink

Welcome to educationLink!

educationLink is designed to provide resources, tools, and information about your fellowship, the history and mission of the DOE, and the roles and responsibilities of its laboratories, particularly in the domain of Environment, Safety, and Health (ES&H) and Security.

When you click on the link below, to access the site, a box will pop up asking for a user name and password. Please use the same user name and password that you chose when you created your applicationLink account.

A description of how to navigate through the site is found at the "**Getting Started**" link, available on every page. If you have any questions or cannot remember your user name or password, you can contact sc.helpwithapplication@science.doe.gov or your Education Director or Program Administrator and we'll help you out.

▸ Enter educationLink!

Forgot your username or password?

Education Links

Office of Science Education Programs
Journal of Undergraduate Research
Other Federal Science Internship Programs
Education Web Sites at DOE Labs and Facilities
DOE Science Careers and Internships
DOE Science Pages for Kids / The Center for Excellence in Education
DOE Resources for Teachers and Students

Security & Privacy

educationLink
...using Pachelbel technology

Got a comment? Contact
sc.helpwithapplication@science.doe.gov

U.S. Department of Energy
Office of Science

educationLink

...science serving the public

Getting Started

Search

Bulletin Board

Syllabus

Resources

Surveys

Abstracts/Papers

We're glad you're here

Welcome to the U. S. Department of Energy (DOE) Office of Science's Laboratory Fellowships online course. We want you to make the most of your experience, so we have developed this online training course to better prepare you for your assignment. We have designed this web site to help you more clearly:

- Understand who DOE and the National Labs are
- Understand what DOE and the National Labs do
- Understand your role at the National Lab during your fellowship
- Understand what is expected of you during your fellowship
- Understand your mentor's responsibilities
- Learn about basic environment, safety & health regulations
- Learn about security regulations
- Learn about the DOE and how its missions have served the public's needs.

Please review these lessons:

- Your Internship
- Department of Energy
- Office of Science
- National Laboratories
- Env., Safety & Health
- Security

These are for your reference:

- Professional Societies
- Job Opportunities
- Other Technical Internships

You have been selected to participate in one of the following unique DOE-sponsored programs: Community College Institute of Science and Technology (CCI); Faculty and Student Teams Program (FaST); Pre-service Teacher Program (PST); or Science Undergraduate Laboratory Internships Program (SULI).

This page is: sys_content/home educationLink

Required Deliverables for Program Participants

Required by all students from the following programs:

- **Science Undergraduate Laboratory Internships (SULI)**
- **Community College Institute (CCI)**
- **Pre-Service Teachers (PST)**
- **Faculty and Student Teams (FaST)**

1. Within your first week at the lab, all students must complete the pre-survey posted on your eduLink account.
2. Write an abstract of your research for submission to the *Journal of Undergraduate Research* and upload the abstract via your eduLink account. Guidelines for submitting a research abstract are in Section B of this Program Guidebook.
3. As required by your lab, you must submit at least one of the following related to the research conducted during your internship:
   a. A written research paper (required for all second term SULI students);
   b. A copy of MS PowerPoint slides used as part of an oral presentation; and/or
   c. A copy of a poster or slides used to construct a poster used as part of a poster presentation. These required deliverables must be uploaded via your eduLink account. Guidelines for these deliverables are also provided in this Program Guidebook.
4. During your last week at the lab, complete the post-survey posted on your eduLink account.

For PST interns ONLY (as specified by your lab):

1. Prepare an Education Module that is inquiry-based, aligned with the National Science Education Standards (see http://www.nap.edu/html/nses/html), and based on your research. Upload this module via your eduLink account.

OR

2. Produce a journal, research notebook, or electronic portfolio that demonstrates your work and thinking regarding the implementation of your research work into a classroom setting. Upload this deliverable via your eduLink account.

Information for Mentors, Master Teachers, and FaST Faculty Members

Mentors

The U. S. Department of Energy appreciates the efforts made by its research scientists and engineers to mentor program interns. Good mentors serve not only as experts in their fields for these future scientists and engineers, but also as role models for lifelong learning and leadership in the scientific community. Thank you for your role in setting high standards for the next generation of researchers.

Mentors are primarily responsible for the safety of program participants in their labs. Please work with your lab education office to ensure that program participants receive the appropriate safety training for the work they will accomplish in your lab. An example of a safety contract, used by the Lawrence Berkeley National Laboratory, is shown on page 13.

Mentors are also responsible for reviewing all student work. Because all abstracts will be published in the *Journal of Undergraduate Research* (JUR), it is especially important that mentors review the abstracts for correctness and to ensure that no proprietary information or otherwise inappropriate material is included in the abstract. Please keep in mind, all abstracts and papers will list students and mentors as co-authors. All abstracts will be subject to one of two grading rubrics depending on the format of the research paper submitted (please see page 17 for the Abstract Rubric and page 18 for the Alternative Paper Format Abstract Rubric).

Mentors should also discuss with students whether or not their research paper should be reviewed for publication in the JUR. This is considered an internal DOE publication that should not preclude the student's work from being published in other journals. However, mentors should discuss this issue with their students and jointly decide if the student's research paper should be reviewed for the DOE journal.

Students whose papers are selected for publication in the JUR will be invited to attend the annual meeting of the American Association for the Advancement of Science (AAAS) in mid-February following their internship. Their abstracts will be published in the AAAS Meeting Program and the students will present a summary of their research at the Student Poster Award Competition.

Students may also elect to have their papers reviewed for publication in the *Journal of Young Investigators* (JYI). This is not a DOE-funded journal; it is a peer-reviewed publication for undergraduate research. More information about JYI is available at http://www.jyi.org. The laboratory and DOE will conduct the first review of research papers from students who elect to have their papers reviewed for possible publication in the JUR. Papers not selected for publication in the JUR may be submitted to the JYI for their consideration.

After mentors have reviewed the student's abstract and research paper or presentation material, **the student should print out a hard copy of the required deliverables (including the abstract) and include a signature by the student author and the mentor.** See the example (page 40) of where those

signatures should be located on the sample title pages in this guidebook. This hard copy should be given to the laboratory education program manager to be kept on file.

Not all research lends itself to publication in the traditional research paper format such as papers on science policy, computer programming, or for students working with proprietary information that cannot be readily shared with the public. In these instances we have provided an Alternative Paper Format (see pages 22 and 62 for details).

Any questions regarding publications of student research work should be directed to the DOE Headquarters Office of Workforce Development for Teachers and Scientists. For more information on mentoring, please log in to eduLink and click on the section "Mentoring Tomorrows Scientists."

Master Teachers

One of the goals of the PST program is to help Pre-Service Teachers become a part of a community of scientists. As scientific community members, teachers will be able to command greater respect from their students and will multiply the resources available to them in their classrooms. Master teachers should work to help students understand the long-term benefits of establishing relationships with people at the laboratory and with the other science and mathematics teachers they meet during this summer experience.

Master teachers should visit their students in the laboratory setting to discuss their research with both the student and mentor scientist. Plan to work closely with your students in both the educational environment and lab settings to ensure your students get the maximum benefit from their research experience.

Discuss local, state, and national standards with your PST students and the importance of having a working knowledge of them. Important national documents include the American Association for the Advancement of Science (AAAS) Benchmarks (http://www.project2061.org/tools/benchol/bolintro.htm), National Research Council (NRC) – Science Education Standards (http://www.nap.edu/html/nses/html), and National Council for Teachers of Mathematics (NCTM) standards (http://standards.nctm.org). State standards in the states where the students hope to be employed or are currently attending school may also be useful to some students. Plan to discuss which standards students feel would be of most use to them as they begin their careers.

Many master teachers find it useful to model mini-lessons for their students based on the inquiry-based model of science teaching. Hands-on activities in which the students actually do the activities has also proven successful, especially for students who have not had much experience with inquiry-based teaching.

PST students will be working to perform research, transform their research experience into classroom lessons, maintain personal journals, and communicate their results in formal research papers and presentations. The master teacher is expected to assist students with each of these tasks and to provide encouragement and support when students feel overwhelmed.

Here are two books that you may choose to use as resources for helping your students think about their teaching and the challenges that await them during their first year in the classroom:

1. Banner, James M., and Cannon, Harold C. (1997). *The Elements of Teaching*. Yale University Press.
2. Palmer, Parker J. (1998). *The Courage To Teach*. Jossey-Bass, Inc.

FaST Faculty Members

The DOE Laboratories provide a unique opportunity for faculty members to work as part of a team with students and DOE research scientists and engineers. It is important that the students on the FaST team look to the faculty member and the DOE mentor scientist not only for information and expertise, but also as role models for life-long learning and leadership in the scientific community. Thank you for your role in setting high standards for the next generation of researchers.

While this is a "team" effort, it is the responsibility of the faculty member of the FaST team to make sure that all student deliverables are submitted to eduLink at the proper time. Like the DOE mentor scientist, faculty team members are responsible for reviewing all student work. Because all abstracts will be published in the *Journal of Undergraduate Research* (JUR), it is especially important that faculty and DOE science mentors review abstracts for correctness and ensure that no proprietary information or otherwise inappropriate material is included in the abstract. All abstracts and papers should list students, faculty, and the DOE mentors as co-authors. All abstracts will be subject to one of two grading rubrics depending on the format of the research paper submitted. Please see page 17 for the Abstract Rubric and page 18 for the Alternative Paper Format Abstract Rubric.

Faculty team members and DOE mentor scientists should also discuss with students whether or not their research paper should be reviewed for publication in the JUR. This is considered an internal DOE publication that should not preclude the student's work from being published in other journals. However, faculty team members and mentor scientists should discuss this with their students and jointly decide if the team's research paper should be reviewed for publication in the JUR.

Students may also elect to have their papers reviewed for publication in the *Journal of Young Investigators* (JYI). This is not a DOE-funded journal; it is a peer-reviewed publication for undergraduate research. More information about JYI is available at http://www.jyi.org. The laboratory and DOE will conduct the first review of research papers from students who elect to have their papers reviewed for possible publication in the JUR. Papers not selected for publication in the JUR may be submitted to the JYI for their consideration.

After the student's mentor has reviewed the student's abstract and research paper or presentation material, **the student should print out a hard copy of the required deliverables (including the abstract) and include a signature by the student author, faculty team member, and the DOE science mentor.** See the example (page 40) of where those signatures should be located on the sample title pages in this guidebook. This hard copy should be given to the laboratory education program manager to be kept on file.

FaST Faculty Member Required Deliverables

Each faculty member must be at the National Lab for the initial 10 week period with at least 1 student and not more than 3 students. The students must be from the same institution as the visiting faculty. All faculty members are required to submit a report on eduLink. This report must be completed by your last week at the laboratory. It is expected that each FaST faculty will at sometime in their collaboration with the National Lab, submit a grant proposal to a granting institution, hopefully in partnership with the National Lab. It will be up to the respective National Labs to set the time limits for grant submittals.

The following is a minimum standard. Any participating Lab may increase the minimum requirements such as requiring a grant submittal at an earlier date or risk dismissal from the program.

Year 1

- Students submit abstract & research paper
- Faculty Member submits a short report via eduLink with copies to the laboratory's FaST Program Manager and Mentor Scientist that includes:
    - Summary of research project (not an abstract), including each student's specific role in the project
    - Benefits (or not) of research experience
    - How FaST experience transmits back to their college/university
    - Faculty member's research goals to begin developing a research grant proposal
    - Comments from mentor or lab education staff

Year 2

- Students submit abstract & research paper
- Faculty Member submits a short report via eduLink with copies to the laboratory's FaST Program Manager and Mentor Scientist that includes:
    - Summary of research project (not an abstract), including each student's specific role in the project. This should show progress from Year 1
    - Response from college/university of the team's Year 1 experience
        - Did the FaST do any presentations at their college/university?
        - Did faculty member submit a report to their Dean/Department chair?
        - Did students receive any credit hours for their internship?

        - Was there an increase in applicants from college/university to SULI, CCI, PST?
        - Did the career choices of student members change? (e.g., major, graduate school)
    - Involvement of mentor & education staff
    - Some progress in development of research grant proposal

Year 3

- Students submit abstract & research paper
- Faculty Member submits a short report via eduLink with copies to the laboratory's FaST Program Manager and Mentor Scientist that includes:
    - Summary of research project (not an abstract), including each student's specific role in the project. This should show progress from Year 2
    - Response from college/university of the team's Year 2 experience
        - Support for development of research grant proposal from Dean/Department Chair, President, etc.
        - Did the FaST do any presentations at their college/university?
        - Did faculty member submit a report to their Dean/Department chair?
        - Did students receive any credit hours for their internship?
        - Was there an increase in applicants from college/university to SULI, CCI, PST?
        - Did the career choices of student members change? (e.g., major, graduate school)
    - Involvement of mentor, education staff
    - Submission of research grant proposal

Sample Safety Contract

Center for Science and Engineering Education
Memorandum of Understanding

Safety Responsibilities for CSEE Participants

Safety is an overriding consideration for all work involving student participants at the Berkeley Lab. In addition to assuring the safety of student participants, the Berkeley Lab wants to instill in student participants an understanding of the safety requirements and processes they will encounter throughout their careers following graduation. Based on these considerations, the undersigned agree to the following safety arrangements:

1. The Student will follow all applicable Berkeley Lab safety requirements. In case of doubt, the Student will consult with the Mentor before proceeding.
2. The Mentor will identify all personal protective equipment the Student will require and will assure that such equipment is available to the Student, and that the student knows when and how to use it.
3. The Mentor will not assign any task to the Student until the Mentor has verified that the student has the knowledge, skills and physical ability to perform the task safely. At a minimum, this will involve an initial safety orientation to the Student's work area and work assignments by the Mentor.
4. Based on the work the Student will perform, the Mentor and the Student will complete a Job Hazard Questionnaire (JHQ) as soon as possible following completion of the New Employee Orientation (EHS 010). The Mentor and the CSEE Supervisor will confer concerning the completion of training identified on the JHQ.
5. Until required training identified through the JHQ process or otherwise is completed, the Student may perform corresponding tasks only under close supervision of the Mentor, i.e., with the full knowledge of the Mentor and while in the same room or area.
6. The Mentor will provide appropriate safety supervision for the Student throughout the Student's stay at the Berkeley Lab.
7. The Mentor may delegate safety supervision as needed to the following qualified Laboratory employees:

_____ _____

_____ _____

Student / Date	**Mentor / Date**	**CSEE Supervisor / Date**
_____	_____	_____
.....	.....	.....

Section B: Writing An Abstract

Abstracts for Research Papers

The abstract provides a brief overview of your entire research in no more than 2500 characters, including spaces, arranged in a single paragraph. The abstract briefly states the research problem or purpose of the research (Introduction), how the problem was studied (Methods), what was discovered (Results), and how the results might be interpreted (Discussion and Conclusions). Acronyms may be used in an abstract, however they should be spelled out the first time they are used. The abstract should stand alone and **NOT** include citations or references within the abstract itself. The names of the participant and the DOE mentor should be given in all capital letters. You may use either first or third person, but must be consistent.

While it is difficult to be both concise and descriptive, that is exactly what an abstract must do. The abstract should be written or updated after the participant's research is completed to ensure that it accurately and fully reflects the participant's work. If the abstract is not updated after the participant's experience is completed, the abstract score may not fully reflect the accomplished research.

Please see page 41 to view a sample research abstract.

Abstracts for Alternative Papers

The Alternative Paper Format is **only** for program participants who meet one or both of the following criteria:

1. **Students are writing a paper on a science topic that does not fit into a research paper format that includes results and result analysis (for example, papers on science policy or computer programming).**
2. **Students are working with proprietary information and cannot readily share their results with the public.**

The abstract for alternative papers is similar to the research abstract in that it summarizes your work in no more than 2500 characters including spaces, arranged in a single paragraph. The abstract should briefly state the subject of investigation or project (Introduction), provide a summary of resources used in your investigation or project (References), provide an interpretation of what you accomplished in you investigation or project relative to other similar projects (Comparison/ Interpretation of Study), and discuss the aspects of your investigation or project that make it unique (Discussion). Otherwise, the format and content for these Alternative Paper Format abstracts should be the same as for the research abstract.

Please see page 61 to view a sample alternative abstract.

Research Abstract Evaluation Rubric

The following rubric will be used to evaluate abstracts submitted by program participants.

Abstracts assigned 0 - 10 points based on:

- (2 pt) Proper spelling, grammar, complete sentences, readability
- (2 pt) Well written introduction
- (2 pt) Methods are discussed
- (2 pt) Results are summarized
- (2 pt) Conclusions are presented

GRADING RUBRIC FOR RESEARCH ABSTRACT	2 Fully meets all requirements and expectations	1 Partially meets requirements	0 Does not meet minimum requirements
Mechanics. **The abstract contains proper spelling, grammar, complete sentences, syntax, diction, and is readable.**	• Contains no spelling, usage, grammar, or mechanics mistakes. • Defines all acronyms except the very common ones.	• Contains two or fewer mistakes in grammar, usage, spelling, or mechanics. • Contains one or more undefined acronym or key terms.	• Contains three or more mistakes • Contains numerous undefined terms.
Introduction. **The abstract briefly states the subject of investigation purpose of project and its context.**	• Gives concise, thorough introduction to provide context and background of project. • Includes statement of the problem being studied.	• Does not define key terms or uses them incorrectly. • Does not give enough information or provides unclear context or background.	• Contains no introduction. • Starts with either methods or results.
Methods. **The abstract identifies how the problem was studied and defines all jargon or acronyms.**	• Discusses what tests/ procedures were used in an organized, clear, and concise manner.	• Discusses methods, but is disorganized, vague, or verbose, or uses lots of jargon.	• Contains no discussion of the method or procedure.
Results. **The abstract has provided an explanation of what was discovered or produced using concise, and specific detail.**	• Refers and connects results to the methods. • Presents results independently of methods. • Gives a justification if no data/results are possible.	• Merely states results [qualitatively]. • If no results are possible, then only says “No results.”	• Gives no results or doesn’t even mention results.
Conclusion. **The abstract interprets the results, evaluates what the results mean to the project, and defines the context within the field.**	• Clearly interprets results and concisely reflects the purpose of the investigation. • Suggests further work (if applicable). • Provides meaning and context to work.	• Reflects the purpose or only suggests further research without providing context.	• Provides no conclusion.

Alternative Abstract Evaluation Rubric

The following rubric will be used to evaluate Abstracts for papers following the Alternative Paper Format:

Abstracts assigned 0 - 10 points based on:

- (2 pt) Proper spelling, grammar, complete sentences, readability
- (2 pt) Well written introduction
- (2 pt) Reference Materials Summary
- (2 pt) Comparison/Interpretation of Study
- (2 pt) Discussion

GRADING RUBRIC ALTERNATIVE ABSTRACT	2 Fully meets all requirements and expectations	1 Partially meets requirements	0 Does not meet minimum requirements
Mechanics. **The abstract contains proper spelling, grammar, complete sentences, syntax, diction, and is readable.**	• Contains no spelling, usage, grammar, or mechanics mistakes. • Defines all acronyms except the *very* common ones.	• Contains two or fewer mistakes in grammar, usage, spelling, or mechanics. • Contains one or more undefined acronym or key term.	• Contains three or more mistakes and numerous undefined terms.
Introduction. **The abstract briefly states the subject of investigation or project and its context.**	• Gives concise, thorough introduction to provide context and background of project.	• Does not define key terms or uses them incorrectly. • Does not give enough information or provides unclear context or background	• Contains no introduction. • Starts with either methods or results.
Reference Material Summary. **The abstract identifies a summary of the resources used in the investigation that might include existing methods, models, programs, or literature.**	• Discusses previous or existing models, research or incarnations in an obvious, clear, and concise manner.	• Contains verbose, vague, or undefined jargon, but does mention other research.	• Does not provide references or references are inappropriate to project.
Comparison or Interpretation. **The abstract has provided an explanation of what was accomplished and/or what compares to similar projects using concise, but specific detail.**	• Clearly, concisely (possibly qualitatively or quantitatively) compares work to prior research, models, or policy.	• Contains disorganized or unclear comparison or interpretation. • States results with little or no comparison or interpretation.	• Merely summarizes work with no context or evaluation.
Discussion. **The abstract evaluates the value and/or uniqueness of the work.**	• Clearly and concisely reflects back to purpose and/or results. • Defines relevance and uniqueness to the field. • Suggests of further work or applications (if possible). • Provides meaning and context of work.	• Contains a discussion, but it may be either vague or verbose in reflection upon purpose, relevance, or future of work.	• Contains no discussion; merely states results.

Section C: Writing the Paper

Research Paper Format

The main body (Introduction, Materials and Methods, Results, and Discussion and Conclusion) of the research paper should be no longer than 10 pages. The Title Page, Table of Contents, Abstract, Literature Cited, Acknowledgments and any tables and figures are not part of the ten-page limit. An electronic copy of your paper should be uploaded to the DOE via your eduLink account, and you should also submit a hard copy to your mentor and your laboratory education program manager before the end of your internship.

The research paper must use the following specifications:

Margins:	**1 inch for all margins**
Font:	**Times New Roman or a similar font**
Font size:	**12**
Spacing:	**Double spaced**
Word Processor:	**MS Word, WordPerfect, LaTex, or PDF file**
Columns:	**One column**

The paper must include the following sections:

Title Page

(See sample, page 40)

Table of Contents

This section lists all parts and page numbers for the paper, including tables and figures.

Abstract

(See sample, page 41)

Introduction/Problem Description

The introduction provides a rationale for the study, clearly states the nature and scope of the problem being investigated, and introduces the study by providing background information and a review of relevant literature. Your literature citations must follow IEEE (Institute of Electrical and Electronics Engineers) format for citations.

Materials and Methods

This section presents, in paragraph format, the materials and procedures used to conduct the research. A numbered list of steps is not appropriate. Instead, describe the research that was conducted, the equipment that was used, and the procedures that were followed. Assume the reader is knowledgeable in the field. Do not describe routine techniques that are already well known. Cite other publications for less well known but lengthy technical procedures.

Results

This section presents, in paragraph format, the data in an organized, refined fashion. Whenever appropriate, create tables and figures that illustrate the data. Do not interpret the results in this section, just describe the findings. Refer to all tables as "Tables" and to all graphs, photographs, or other illustrations as "Figures." List statistical operations where appropriate, e.g., "ANOVA" or "Student t-Test." At the bottom of each figure or table must be a complete but concise caption with an explanation of the data including any relevant statistical information, such as confidence limits, that might not be directly shown on the figure. Tables and figures should be included at the end of the paper and NOT included within the text of the paper.

Discussion and Conclusion

This section describes your interpretation of the research results, relates the results to the original purpose of the study, compares the findings with other existing research, and discusses whether your findings agree with other researchers' results and interpretations. Because conclusions are drawn from findings presented in the results section, you should refer to the specific data that support your conclusions. Also include plans for further research that directly relates to your work.

Literature Cited

When information or an idea is taken from another source or referred to directly or indirectly, it must be cited in the text and the origin of the information listed in this section (similar to a bibliography). Citations must be in IEEE format. For some examples of citations of IEEE format or instruction in using this format if you are unfamiliar with IEEE format, please see:

http://www.ecf.utoronto.ca/~writing/handbook-docum1b.html
http://www.class.uidaho.edu/adv_tech_wrt/resources/sources/bibliographic_ieee_format.htm
http://www.computer.org/cspress/instruct.htm

Acknowledgments

In this paragraph, mention where and when the research was accomplished and acknowledge the people who provided major assistance with your research. Acknowledge the U. S. Department of Energy, Office of Science and your host lab for creating, organizing, and funding the program. Also, if your internship has been partially sponsored by the National Science Foundation, thank the NSF for their help in funding the program.

For examples of previously published papers visit:

http://www.scied.science.doe.gov/scied/JUR.html

Alternative Paper Format

The Alternative Paper Format is only for students who meet one of the following criteria:

1. **Students are writing a paper on a science topic that does not fit into a research paper format that includes results and result analysis (for example, papers on science policy or computer programming).**
2. **Students are working with proprietary information and cannot readily share their results with the public.**

Students should keep in mind that the Alternative Paper Format still requires an abstract, which must be submitted by all students. However, students submitting a paper using the alternative paper format should carefully review the abstract prior to publication to ensure that the abstract does not include any proprietary information. In all cases, students should have their mentors review and approve their abstracts.

The main body of the Alternative Paper should be no longer than 10 pages. The Title Page, Abstract, Author Biography, Table of Contents, Literature Cited, Acknowledgements and any tables and figures are not part of the ten page limit. Literature citations must follow IEEE format. An electronic copy of your paper must be submitted to the DOE online via the eduLink website, and you should also submit a hard copy to your mentor and your laboratory education program manager before the end of your internship.

The Alternative Paper must use the following specifications:

Margins:	**1 inch for all margins**
Font:	**Times New Roman or a similar font**
Font size:	**12**
Spacing:	**Double spaced**
Word Processor:	**MS Word, WordPerfect, LaTex, or PDF file**
Columns:	**One column**

General Description

The Alternative Paper is a review article format, much like that seen in *Scientific American* articles. In initial paragraphs of the paper, the relevance and the importance of the subject matter should be made clear. In the first section (approx. 500 words), the author should lay a solid foundation of what is known in the field. The body of the paper should address the research and/or project work accomplished by the student. The latter portion of the paper should try to bring together any controversies and point to future experiments. Alternative Papers must include the following:

1. **Title Page (See sample, page 40)**
2. **Table of Contents**

3. **Abstract** (See sample, page 41)
4. **Body of Paper** (See sample, page 42)
5. **Literature Cited** (See sample, page 52)
6. **Acknowledgements** (See sample, page 52)
7. **Figures and Tables** (See sample, page 54)

Guidelines for Submitting Final Papers for Review for Publication in the Journal of Undergraduate Research

These are the guidelines that you should follow only if you are requested to submit your paper for inclusion in the *Journal of Undergraduate Research* (JUR). These guidelines apply to both research papers and alternative format papers. These guidelines are meant for the final step, after the papers have gone through the peer review process and you have made all the necessary changes. The guidelines below need to be specific for any paper that is to be published because of the strict requirements of the CMYK (cyan, magenta, yellow, black) printing process and the high resolutions needed for quality glossy publications such as the JUR. See the last paragraphs of these guidelines for more details about image formats and the CMYK printing process.

Basic Paper Formatting

Your paper must follow the guidelines for publication as explained in this Program Guidebook (also online at http://educationlink.labworks.org/media/guidebook.pdf), including the proper use of IEEE format for the bibliography.

All papers will be reformatted during layout with a common font, size, columns, margins, etc. Please deliver a paper that is as straightforward as possible for translation into our final format. This includes using MS Word or another standard software package and not using any unusual characters. (Times or symbol fonts only. If it is necessary to use an unsupported special character, you will need to submit the font file as well).

The final format will be a two column paper, very similar to the previous versions of the JUR which you can review online (http://www.scied.science.doe.gov/scied/JUR.html). It is also recommended that you look through professional journals (such as *Science*) to better understand how these papers are different than term papers.

Equations

Some equations belong inline with the text. If your equation should stand alone in the paper, you may use equation editor in MS Word or a similar program to generate the equation and paste it into the MS Word document. If you are providing it as a separate file, please make sure it is in a vector and text

based format, not a bitmap picture. If it does not fit inline, then the equation must be referenced in the body of the paper.

Captions

All visuals (i.e., tables, figures, pictures, drawings) need to have appropriate captions. These should be provided as standard text and numbered (e.g., Figure 3, Table 2, etc.). All visuals will appear within the body of the paper (not at the end) and all captions will appear below their corresponding visual.

Visuals

Visuals fall in several categories with different specifications, as described below. See the separate section explaining Vector images and CMYK vs. RGB (page 25 and 26) if you are unfamiliar with these graphics issues. The JUR will be in two column format, meaning the standard visual will be about 3 5/8" wide. When appropriate, images may be smaller or larger. Please keep this in mind as you prepare your graphics. They must be clear and readable. This means color choices and resolution and text size must be appropriate. All visuals should be submitted as individual files and not embedded in a document.

Clustered Visuals

When you have data that is best expressed in a series of images or graphs, you need to make sure that all the graphs are consistent in size, axis scale, and all other formatting. When appropriate, a single caption can explain a cluster (e.g. Figure 3a and 3b on page 56).

Tables

Use tables sparingly. We do not want to include "data dumps" in the journal. The data should be a refinement of raw data and should be both well organized and labeled. Proper units should be included. The inclusion of a data set (or partial data set) should advance the reader's understanding of the research and should be referenced in the paper. Tables should be sized appropriately, and may be placed in a single column, or may span both columns in the journal. Please provide an editable but formatted table in your MS Word document or as a separate file when appropriate.

Graphs and Charts

Please be sure to include original files with your submission. Clipboard copies and/or embedded images are often difficult or impossible to use. If you are using a software package that is less common, please export the image as a vector based file and include the file in your submission. Graphs and charts should be vector based files. Please look at similar scientific journals (such as *Science*) for examples of how graphs are included. Notice that they often take up a small amount of space and so they need to be presented efficiently. This means that MS Excel graphs (which by default make the legend almost as big as the graph) need to be reworked. Additionally, the fonts used for labels should be sized appropriately for the small size. Please keep all backgrounds transparent unless you have a reason to do otherwise. A standard

graph will be 3 5/8" wide (one column). All work should be done in CMYK whenever possible. Black text and lines need to be defined as true black (K). MS Excel and other programs do not have this adjustment, but with the original files the transformation can be made later.

Drawings

Please use a vector based drawing program for any drawings that you submit. Adobe Illustrator is best. MS Word's drawing tools are adequate, but make sure all objects are properly grouped. Do not use a program such as Paint. It does not have the proper resolution or editing options. All color drawings should be done in CMYK format. Black must be true black (not the RGB approximation).

Screen Captures

Screen captures should be done only when necessary, and should be done at the highest resolution possible. Images of screens should be trimmed to include only what is important for the reader to see (cropping, menu bars, etc.) where appropriate. Captured images should be saved directly as an image file and not incorporated into a MS Word or other document. These screen captures, by their nature, will be RGB and should be converted to CMYK with the additional step of all lines/text that appear black must be converted to true black (K).

Photos

Any picture taken with a camera or scanner should be preserved and delivered in the highest resolution possible. If possible, the image should be in an uncompressed format (such as .tiff). Jpeg images have a habit of blurring sharp lines and text, and repeated saving of the file causes a compounding of the compression errors. Resolution must be at least 300 dpi and the image size should be appropriate to the expected final layout size. Usually this is 3 5/8" (one column) wide.

File Formats

The preferred formats for visuals is Adobe Photoshop (.psd), Adobe Illustrator (.ai), .tiff, .eps, .emf. All files should be in CMYK mode with a resolution of 300 dpi. Avoid using the windows clipboard unless you really know what you are doing. The clipboard copies objects at screen resolution (72 dpi RGB).

Vector vs. Raster (or bitmap) Images Explained

Many of us who have used a modern font understand that as the font is scaled up in a word processing program like MS Word, the curves get more detailed and the choppiness decreases. You may also have noticed that the choppiness you see on your screen (72 dpi) is not present when you print it (300 or 600 dpi). This is possible because modern fonts are built in vector format. The simplest example is a line. It is defined by two points in a vector file, but as a string of dots in a bitmap. As you zoom in on that line, the bitmap version shows its dots, while the vector continues to be a line. Additionally, a vector based graphic keeps every line and letter as a separate object. This is critically important when we need to correct color problems. We can apply a change to a single element and be sure that the entire object

is converted properly. Bitmaps (including tiffs and compressed bitmaps like jpegs) are flat images with different colors mixed together and pixilated. Software can sometimes separate different colors, but never with 100% accuracy or with the ability to maintain sharp boundaries between objects. Photos should be bitmaps. Drawn objects (including graphs) should be vectors.

CMYK vs. RGB Explained

A computer monitor uses red, green and blue light to create all colors that you see (look with a magnifying glass, or look at your low resolution television). Every color is defined as a clustering of different amounts of each color of light. Yellow is obtained by mixing red and green, black is obtained by leaving all colors off, etc. When we print, those screen colors must be approximated by ink that works by laying down different levels of dark rather than different levels of light. The dots of color (cyan, magenta, yellow, and black) are placed very close together in different darknesses to create the colors that we want in the printout. The conversion process from RGB to CMYK can cause many colors to come out of the printer slightly different than what we see on the screen. This isn't bad unless the color is critical (skin tones) or detailed. The biggest problem is thin black lines. A black line on the screen (R=0, G=0, B=0) is converted to a line on paper (C= 20, M=33, Y=15, B=83) in some approximate way that looks black-ish. The problem is that for a thin black line, the C,M,Y that you find mixed in, will often show up clearly around the edges. Most people have experienced this with their inkjet printers from time to time, especially when printing text that isn't printed as true black and especially when the print heads are misaligned.

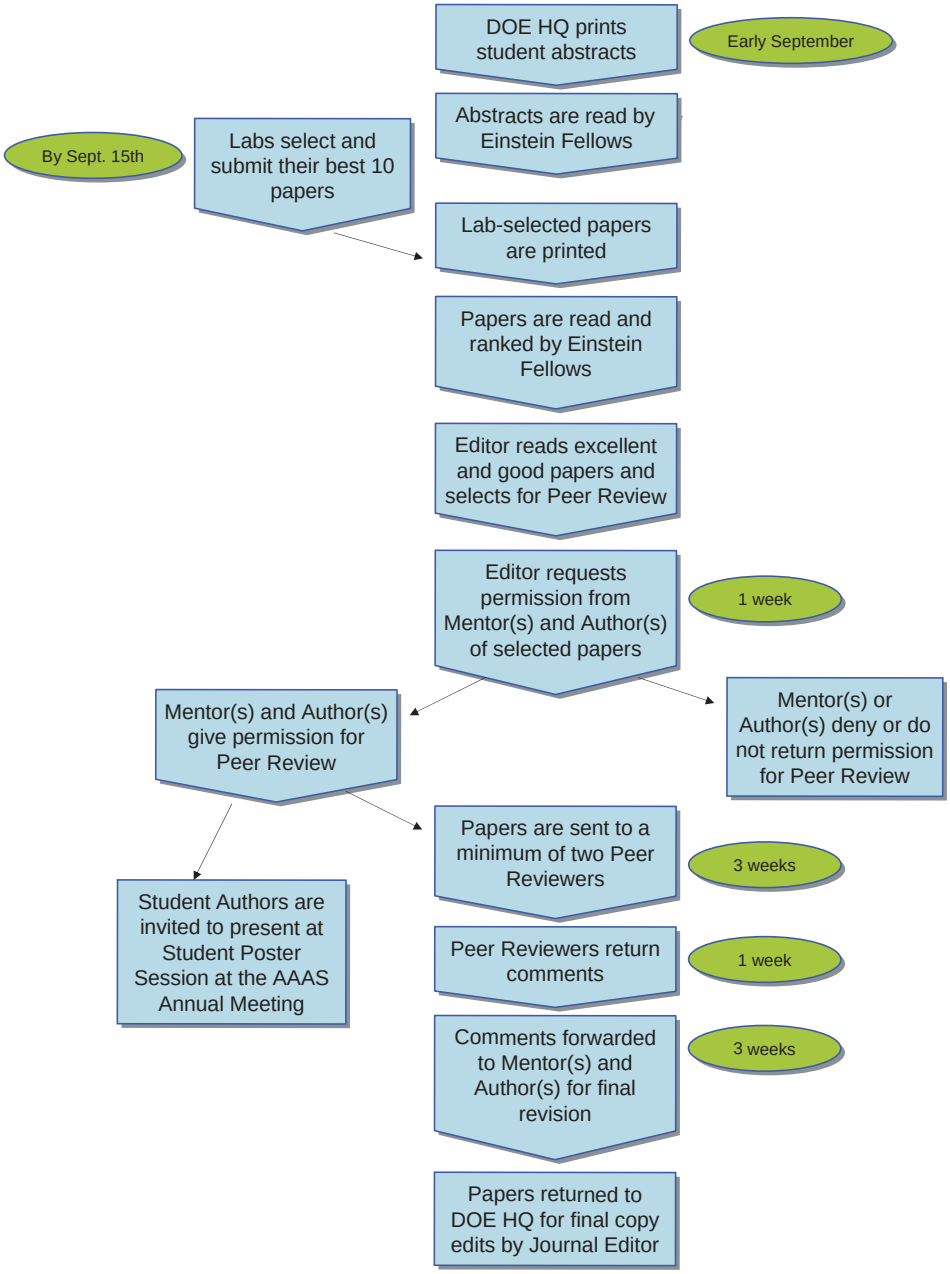
To maintain the quality of a publication such as the *Journal of Undergraduate Research*, we must go into every file and convert each black line from an RGB value to a CMYK value of (C=0, M=0, Y=0, K=100) in order to have a true black line. Similarly with text that is embedded in an image or graph. This problem is manageable to fix with vector based drawings, but is very difficult with pixilated drawings and impossible with compressed image formats.

Problems

If any of the graphics come to us in a format that we cannot work with, we may be contacting you for a different version or asking you to clean up the images for us. Most submissions require at least one or two communications with the authors. Please contact us with any further questions or concerns. Proper submission format is necessary for your article to be printed. It may be necessary to reject a paper if the authors are not able to provide visuals of a suitable quality.

Section D: Publication Process

Process for Reviewing and Selecting Papers for the Journal of Undergraduate Research



Section E: Presentations

The Oral Presentation

The oral presentation should have an approximate duration of 15 minutes. The objective of an oral presentation is to communicate information to other scientists. Elements of an effective oral presentation include:

The Speaker

- Keep in mind that your objective is **communication of information.** Mumbling, monotone speech, and use of obscure terminology are not effective methods of communication.
- Engage the audience. An oral presentation can be informative, exciting, and even humorous.
- You are a speaker, not a reader. Take advantage of the verbal medium.

Presentation Materials

- Use visual aids whenever possible. A picture is worth a thousand words and a graph is worth a thousand numbers.
- A picture is worth a thousand words only if the purpose of the picture is clear. Clearly introduce any graph, table, or picture. It is often difficult to read graphs on overhead projections, so

verbally repeating some things (such as the legend and axes of a graph or the magnification of a micrograph) can assist the audience.

- Demonstrations, models, short videos can all be effective means of communication.
- Limit the number of slides or frames in an MS PowerPoint presentation. Too many slides can be distracting from the main point of your research.

The Structure of the Presentation

- At the start of the presentation the speaker should introduce herself/himself and identify both the sponsoring organization and other contributors to the research.
- As in most technical presentations, it is best to give some background information on the subject. This allows both the speaker and the audience to place the topic in perspective before the technical information is presented.
- Clearly communicate what you intended to accomplish in your work and how your research relates to the larger body of research in the field.
- Do not spend time describing the details of well-known techniques.
- If you made little progress during your research, describe what problems held up your progress and how, if given more time, you might have overcome those problems.
- Describing plans for future experiments is a common way to end a presentation.

The Poster Presentation

Purpose

The primary purpose of the poster presentation is to provide an opportunity for communicating the results of research and to promote discussion among science colleagues. Because poster presentations are usually done in groups, with observers milling around a large room of posters, the presentations are relaxed and more conducive to the exchange of ideas and techniques between presenters and observers.

The poster presentation's main body (Introduction, Methods and Materials, Results and Discussion) should be no longer than 15 slides. The Title Page, Table of Contents, Abstract, Literature Cited, Acknowledgements and any tables and figures are part of the fifteen-slide limit. An electronic copy in MS PowerPoint must be uploaded via your eduLink account. You should also submit a hard copy to your mentor and your laboratory education program manager before the end of your internship.

The Poster

A good poster is uncluttered and clear in design. It has legible text and logical organization. The main tenet of a good poster design is simplification. Use a crisp, clean design and a strong title. Do not tell the entire research history; present only enough data to support your conclusions and show the originality of the work. The text material should be reduced to convey your points quickly and clearly. Many successful posters display a succinct statement of major conclusions at the beginning, followed by supporting text in later segments, and a brief summary at the end.

- Allow ample time, at least two weeks, to prepare your poster.
- All lettering should be legible from about 5 feet (1.5m) away.
- Text material is ideally

24 point (1/4", .625cm)

Poster elements should be mounted with an adhesive on white or colored poster board. A professional appearance is achieved by mounting illustrations and captions on colored poster-board with a ¼" to a ½" border as a frame. Double mounting with different colored poster board is a clever way to color coordinate different sections of the poster.

For ease of transport, make the poster elements small enough to package and carry (approximately 17" x 22", 42.5cm x 55cm). Be sure to pack a measuring tape, push pins or Velcro, and a sketch of the poster layout so you will be prepared to set up the poster quickly.

Posters should feature a title, your name, the name of the institution where the research was performed, the sponsor (Department of Energy), and should credit persons who have helped you with your research.

Preparation

- The top of the poster should consist of an easy-to-read and easy to understand Title that includes author(s) name(s). The title lettering should be about 2" to 3" (5cm to 7.5cm) with subheadings ½" to 1" high (1.25cm to 2.5cm).
- All lettering should be legible from about 5 feet (1.5 m) away. The appropriate type size for text should be 24 points (¼", .625cm).
- The component parts should be organized in a way that leads the viewer through the display. Colored matting can be very effective here.
- Leave some open space in the design.
- Use elements of different size and proportions. Convert tabular material to graphic display, if possible.
- A large and/or bright center of interest can draw the eye to the most important aspect of the poster. Use color to add emphasis and clarity.
- Make illustrations simple and bold. Enlarge photos to show pertinent details clearly.
- All illustrations, graphs and pictures should have their own attached explanations.
- Displayed materials should be self-explanatory, freeing you for discussion.
- Handouts of your abstract should be available for interested viewers.
- Demonstrations of experiments or three-dimensional displays are not typical of a poster session.

*These guidelines were taken, in part, from the AAAS-American Junior Academy of Science Poster Session guidelines for the year 2007.

Section F: Everything Pre-Service Teacher

The Education Module Template

(See sample, page 78)

Title

Name of lesson plan.

Author

Name of author.

Grade Level/Subject

Mention all the subjects that will be included in your lesson plan as well as grade level(s).

Curriculum Standard

List the AAAS, National Science Education Standards – National Research Council, NCTM, state or national standards that this lesson plan meets.

Overview

A brief summary of your activity.

Learning Objectives

What will students learn or accomplish from completing this lesson?

Time Allotted

How much time will you need to teach your entire lesson?

Vocabulary

List the words that students need to be familiar with in order to understand the material that will be covered in this lesson plan.

Resources/Materials

List supplies or resources needed (encyclopedias, Internet resources, email, newspapers, handouts). If you use handouts, list the handouts that students will use during the lesson.

Note: For each of the following sections, list specific steps you would take to carry out the lesson.

Prerequisite Knowledge

What does a student need to know before beginning this activity?

Main Activities

List the steps needed to introduce the activity to students. Do you make a presentation to the entire class or to small groups of students? List steps for body of lesson.

Evaluation

How will you assess student's acquisition of knowledge or demonstrate student's progress toward the standards that your lesson addresses?

The Personal Idea Journal

During your time as a Pre-Service Teacher intern, you will have many opportunities to document the processes of science which can then be integrated into your future classroom. The personal idea journal is designed to help you document these opportunities in a way usable to you. The following is a listing of possible organizational strategies that you may follow, but you may choose any format that makes sense to you and that you would use as you begin your first teaching position.

Possible Organizational Strategies

1. **Timeline.** This organizational method documents integration ideas as you encounter them in your internship. Some people remember where things are if they have a chronological ordering to look back on and refer to.

2. **Subject Listing.** Since you may be teaching a variety of subjects related to math or science, you may find it useful to divide your journal into subject specific areas such as Classroom Management, Language Arts, Computer/Technology, Chemistry, Physics, Life Science, Math, General Science, etc. List the grade level most appropriate for each idea.

3. **Grade Level.** You may not know the grade level of your first teaching assignment, therefore a listing of grade level ideas may be the most beneficial. Sorting by early elementary, intermediate grades, middle grades 6-8, and 9-12 grades is one idea. In the high school grade level list make sure to list the subject area to be covered, e.g., chemistry, physics.

4. **Topic Areas**. This list will include ideas organized into a format based on broad scientific and mathematical themes. You may include all activities related to Energy, Magnets, Light, Sound, Alternative Energy, Weighing, Volume, General Education, Processes of Science, etc. All activities, regardless of the grade level, will be included in your theme listing. Remember to include the intended grade level. This format is a good method if you are unsure of what grade level an activity is appropriate for, or are interested in teaching a variety of subjects and grade levels. Many ideas could be used at several grade levels simply by adjusting the content up or down.

Requirements

During your internship, it is expected that you will be able to develop at least one integration idea per week. You should include as many details as possible so that when you develop the lessons in greater detail in your classroom, you have a useful outline to follow. Ideas to include in your journal might be: materials, objectives for students to attain, time allotted (one class period; ½ hour etc.), instructional methods, assessment ideas, etc. Even if you change these thoughts once you begin teaching, they will provide you with valuable information to ensure that your lab experience is relevant to your classroom instruction.

Integration Ideas

Below is a list of possible scientific processes that you may encounter at your lab which could be integrated in quality classroom lessons. These suggestions will help you understand what types of ideas should be included in your journal.

(Note to Laboratory Education Staff – For each of the ideas listed below, please provide an actual example, where appropriate, from your lab, of what this activity might look like. For example, in the teamwork section, your scientists might work with a team spread throughout the world and they have worked out methods for communication. Please include as many specific, concrete examples as you can so that the students understand what is expected in their journals.)

1. How scientists work – teamwork, working out differences in an agreeable way, and communicating with collaborators
2. Scientific labs workable in the classroom – list by topic area such as Chemistry, Physics, Earth Science
3. Computer use – technology – programming ideas – keyboarding
4. Conducting meetings – brainstorming – communication
5. Creating a lab notebook
6. Computer documentation of lab results and how scientists use computers
7. Math calculations and ways that scientists use mathematics including measurement, error documentation and statistics
8. What happens when research doesn't work out the way that was expected? How do scientists take set backs and re-adjust so that even apparent failures can reveal important discoveries, and how can you use this information in your own classroom when your experiments appear to have failed?
9. Collecting data and recording results
10. How do scientists learn new information – meetings, seminars, colloquia, etc.
11. Simple early grade explorations that pertain to the complicated subject specific research at the lab, such as electromagnets, circuits and basic atomic structure, if you are involved in research at an accelerator facility. Try to take the concepts from your research or the design of the facility and digest them down to the basic elements that even an early elementary student could understand.

During your laboratory experience you will have experiences that can influence your future teaching. These ideas can be developed as ways of making teaching and learning more like doing science. These ideas can also be included into your journal in any format that will be of future use to you in your classroom.

Here is an example that actually occurred at one of our National Laboratories and illustrates how a future teacher used what happens when research does not go as expected within their teaching. He observed what research teams do when research doesn't go right. What can one learn from this experience to help your future students when their experiment doesn't work as they expect?

One high school teacher had a class whose experiment produced meaningless data. Ordinarily he would have gone right on the next day to the next lesson. However, because of his research experience, he realized that scientists would fix what went wrong before continuing with their research. He asked his

students to discuss problems in their data, then redesign and repeat their experiment. They did, and the second time the students got good data.

Here's another example: a teacher changed her whole teaching approach so that now she tells her students she is the theorist and in this role introduces topics, explains concepts, etc. Students are the experimentalists who must design and conduct experiments to test her theories. In this way she has students coming up with and analyzing "research questions" instead of doing cookbook experiments. As PST interns, try to look for ways scientists work and solve problems that can be translated to the classroom. The primary aim of this journal is to help you integrate these laboratory experiences into your future classroom. The above lists of organizational and integration ideas are only a brief set to get you started thinking about how to gain the maximum benefit from your lab experience.

The Digital Portfolio

This deliverable for Pre-Service Teachers may include any of the following elements that can be recorded in a digital format. This is only a partial list, so feel free to include any further items that would be useful to you in your future classroom:

1. A reflective journal
2. Lesson plans related to research at the lab (these could involve different types of activities, e.g. a field trip to the lab, use of technology, use of scientific data, science careers, an experiment, a hands-on, inquiry activity, etc.)
3. Observations of science lessons (Department of Energy Academies Creating Teacher Scientists (ACTS) teachers, if available at your lab, or summer school) and subsequent analysis of the lessons
4. Videotape of microteaching (PST interns teaching 15 minute lessons to their peers)
5. A research paper on a science topic
6. A science teaching aid (e.g., a physical model, web site, computer software, demonstration, game, an online quiz, tutorial, etc.)
7. Attendance at scientific presentations/lectures followed by short articles describing what they have learned and how it might be applied in the classroom (these could even be submitted to an National Science Teachers Association (NSTA) journal for possible publication)

All of the above should be related to the scientific research that you are involved in at your lab. This digital portfolio is required to be uploaded via your eduLink account.

Section G: Samples, Samples, and More Samples

Sample Title Page

Thermophoresis and its Thermal Parameters for Aerosol Collection

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Lawrence Berkeley National Laboratory
Berkeley, California

January 14, 2007

Prepared in partial fulfillment of the requirement of the Office of Science, Department of Energy's Science Undergraduate Laboratory Internship under the direction of Michael G. Apte in the Environmental Energy and Technology division at Lawrence Berkeley National Laboratory.

Participant: _____
Signature

Research Advisor: _____
Signature

Sample Research Abstract

ABSTRACT

Thermophoresis and its Thermal Parameters for Aerosol Collection. ZHUO F. HUANG (Sacramento State University, Sacramento, CA 95819) MICHAEL G. APTE (Lawrence Berkeley National Laboratory, Berkeley, CA 94720).

The particle collection efficiency of a prototype environmental tobacco smoke (ETS) sampler based on the use of thermophoresis is determined by optimizing the operational voltage that determines its thermal gradient. This sampler's heating element was made of three sets of thermophoretic (TP) wires 25 μm in diameter suspended across a channel cut in a printed circuit board and mounted with collection surfaces on both sides. The separation between the heating element and the room temperature collection surface was determined in a numerical simulation based on the Brock-Talbot model. Other thermal parameters of this TP ETS sampler were predicted by the Brock-Talbot model for TP deposition. From the normalized results the optimal collection ratio was expressed in terms of operational voltage and filter mass. Prior to the Brock-Talbot model simulation for this sampler, 1.0 V was used arbitrarily. The operational voltage was raised to 3.0 V, and the collection efficiency was increased by a factor of five for both theory and experiment.

Sample Research Paper

1. INTRODUCTION

Particulate matter (PM) is comprised of both solid and liquid particles that are suspended by gas molecules in the air. The composite mix of PM and the air in which it is suspended is defined as an aerosol. According to the U.S. Environmental Protection Agency (EPA), PM-2.5 and PM-10, which are particles with aerodynamic diameters less than 2.5 and 10 μm, respectively, can cause adverse health effects with even short-term exposure. Environmental tobacco smoke (ETS) exposure increases the risk for respiratory diseases and lung cancer. The involuntary exposure for children (through secondhand smoke) causes lower respiratory illness in their infancy and early childhood, and adverse effects on lung function across childhood [1]. Given the important public health implications of PM exposure, a continued need exists for development of cost effective, accurate, and practical measurement devices [2]. Various prototype instruments are being developed to measure the mass, size, and chemical composition of PM. Development of this device is motivated by the aim of obtaining a better exposure assessment tool to remedy misclassification of ETS exposure in epidemiological studies (see [1] Chapter 1 for details). This device measures particle phase (ETS) and gas phase (nicotine and 3-ethenyl pyridine) ETS exposure. This portion of the project was focused on the ETS deposition mechanism of the particle phase sampling device.

The use of van der Waals induced dipole-dipole attraction is sufficient for surface retention of micron and sub-micron sized particles. Thermophoresis, the normal force on a particle created by the momentum transfer along the decreasing direction of a thermal gradient [3], is an effective method for particle collection in validating traditional methods [4]. When an aerosol is flowing in a narrow channel, the thermal gradient strength determines the strength of thermophoretic (TP) forces on the particles.

Experiments were conducted with a new device developed to sample airborne particles in indoor air with support from the California Tobacco Related Disease Research Program (TRDRP). Seeking a better understanding of thermophoresis to improve the collection efficiency became a motivation for exploring the theories dealing with TP particle deposition in laminar flow regimes in ducts (~500 μm high). In a series of particle phase experiments using a TP ETS sampler, the TP voltage that controls its thermal gradient in the sampler was increased until the optimal (maximal) ETS deposition was determined.

The Brock-Talbot model for TP deposition [5] was previously used for proof of concept. In this project, this model was extended over a larger particle size range. A second purpose was to compare theoretical predictions with the experimental performance of the TP ETS sampler. The sampler used TP wires (California Fine Wire Co., Grover Beach, CA, Nickel Alloy 120) of 25 μm in diameter to heat up the surrounding air by applying a voltage across the wires. An arbitrary operational voltage of 1.0 V was selected for powering the TP wire prior to computer simulation and chamber experiments. Since the temperature of the wires was proportional to the applied voltage, establishing the temperature-voltage relationship was useful for obtaining optimal collection.

2. MATERIALS AND METHODS

i. Theoretical Model

In the presence of a thermal gradient, the phenomenon of thermophoresis becomes significant in influencing particle motion [6]. TP deposition is based on a temperature difference between two close surfaces; given the appropriate gradient and particle size range, the collection can be 100% efficient [3]. The TP force is very effective for depositing tiny particles flowing through a channel onto its cooler surface. Other than the temperature gradient, many other

parameters such as thermal conductivity, dimension of the flow channel, and viscosity associated with the particle stream play important roles.

The Brock-Talbot TP force model given by He and Ahmadi [5] is

$$F_{th} = 2\, C_s\, C_c\, \frac{1}{\tau}\, \nu\, H\, \frac{\nabla T}{T}\, m \quad , \tag{1}$$

where C_s is the thermal slip coefficient, and C_c is the Stokes-Cunningham slip correction

$$C_c = 1 + \frac{2\,\lambda}{d}\left(1.257 + 0.4\, \mathrm{Exp}\left[-1.1\, \frac{d}{2\,\lambda}\right]\right) \quad , \tag{2}$$

and τ is the relaxation time in equation (1) given by

$$\tau = \frac{S\, d^2\, C_c}{18\, \nu} \quad . \tag{3}$$

S is the ratio of particle density to fluid density [7]. T and ∇T are the room temperature and thermal gradient; m is the unit mass and ν is the kinematic viscosity of the molecules. H is the molecular accommodation coefficient given by

$$H = \left(\frac{1}{1 + 3\, C_m\, Kn}\right)\left(\frac{\frac{k_a}{k_p} + C_t\, Kn}{1 + 2\, \frac{k_a}{k_p} + 2\, C_t\, Kn}\right) \quad . \tag{4}$$

This equation indicates the relationship between particle diameter and thermal conductivity. Talbot found the values of the coefficients C_s=1.17, C_t=2.18, and C_m=1.14. C_t is a number of order unity which relates to temperature jump [5], and C_m is the momentum exchange coefficient that depends on the particle-gas configuration, and [5, 7]. Kn=2 λ/d is the Knudsen number, where λ is the mean free path of air and d is particle diameter; k_a and k_p are the thermal conductivity of gas (air) and particle respectively.

The TP collection ratio

$$\eta = \frac{U\, L}{2\, h\, u_m} \tag{5}$$

is the ratio of the TP velocity and the mean air velocity u_m of the channel. Here, L and h are the length and the height of the channel and, and they are chosen to be 71.0 mm and 0.5 mm for the simulation, reflecting the dimensions of the TP ETS sampler. U is the TP velocity

$$U = \frac{F_{th}}{m}\tau, \qquad (6)$$

which in effect determines the TP collection ratio. Substitute τ and H into Equation (1) and expand in terms of its dependent parameters, the equation becomes

$$F_{th} = 36\,C_s \frac{\nu^2}{S d^2}\left(\frac{1}{1+3C_m Kn}\right)\left(\frac{\frac{k_a}{k_p}+C_t Kn}{1+2\frac{k_a}{k_p}+2C_t Kn}\right)\frac{\nabla T}{T}\,m. \qquad (7)$$

The C's are collectively referred to as the drag forces. One can see that the TP force strength is inversely dependent on particle diameter and the temperature of forming the thermal gradient, where ν and k_a/k_p dependence are accounted for the type of particles. This equation is simulated with the molecular diameter of air chosen to be 5.7 nm, and the aerosol particles consist of NaCl (for consistency with the reported work in [5]) with thermal conductivity k_p=6.69 W m^{-1} K^{-1}.

ii. Apparatus

The collection apparatus consists of a loom-like frame machined from a copper clad printed circuit board that holds a set of TP wires and acts as a flow channel, and a mounting surface for fin-cooled aluminum particle collection surfaces. When assembled, the device becomes an air-tight flow-through channel with three sets of TP collection areas; a small pump of flow rate 0.01 L/min was used to draw a PM-laden air sample through the device. Four fine TP wires of 25 μm in diameter about 5 mm in length were soldered, physically in parallel, and electrically in series to form a coplanar resistive heater about 5 mm on a side on the collector frame. Three of these heaters were assembled on a single sampler to create three separate TP collection regions (see Figure 1). When the TP ETS sampler was assembled and a voltage was

applied across one of the three wire circuits, a thermal gradient was formed (see Figure 1 thermogram insert for heated wires image) between the wires and the fin-cooled aluminum collection surface.

Two collecting surface configurations were used on the two sides of the TP wire blocks for particle collection. An aluminum collection surface (see Figure 1), was fabricated with a polished thin aluminum surface attached to an aluminum body with double-sided heat conducting tape. A glass collection surface (opposite) was assembled with a thin glass cover slide and another aluminum body. The glass cover slide was glued at edges to allow light transmission through two circular pinholes of diameter ~ 1 mm that were each centered on a TP particle deposition area on the surface. LEDs (Roithner Lasertechnik, Vienna, Austria, UV-LED 380D30 and ELD-810-525) of peak wavelength of 380 nm (UV) and 810 nm (IR) were inserted into the back of the aluminum body allowing a light beam to be transmitted through the pinholes and to emerge normal to the glass surface. The LED pinholes were located in the center of the TP deposition surfaces for two of the three collection areas on the glass-covered collection body.

iii. Thermophoretic Wire Temperature

In Figure 1, the thermogram insert shows the heated TP wires. Due to the low emissivity of the wires, the thermogram merely indicates the wires were hotter than their surroundings when powered, yet does not accurately indicate the *exact* temperature. Using an alternate approach to thermography, the approximate temperature of the TP wire could be calculated in terms of resistance with the known temperature coefficient of resistance of the TP wire provided by the manufacturer. A 50 x 50 x 80 cm convection oven was used to measure the temperature-resistance relationship of the TP wires. A differential temperature controller gradually raised the temperature while two small 12 V fans were used for air mixing inside the oven. A sampler was

placed inside the oven and two blocks of TP wires' resistance were measured for comparison. The resultant voltage vs. temperature relationship could be obtained for determining the associated temperature with experimental voltage and current using Ohm's law.

iv. Experiment Setup and ETS Generation

A 24 m^3 environmental chamber built with wood frame, wallboard walls and ceiling, and magnetic refrigerator door seals. Low volatile organic compound emitting paints and sealants is applied inside the chamber to minimize unwanted room-ambient particles and volatile organic compounds [8]. The chamber is bolted stationary in a one-story building, no ventilation equipment was used, and the room temperature stayed approximately steady during the sampling periods. The TP ETS sampler was hung from a stand 0.5 meters above the floor, side by side with the a Personal Environmental Monitor (PEM) PM-2.5 sampler (SKC Inc., Eighty Four, PA, 761-203). The PEM, assembled with a Teflon-coated fiberglass filter (SKC Inc., Eighty Four, PA, SKC Filter 761-203) and sampling at a rate of 2.0 L/min, provided the integrated PM mass concentration in the chamber during the sampling period. Using the proportionality of the integrated PM mass concentration and TP ETS sampler flow rates, the total particle mass that traversed the TP ETS sampler during operation was calculated.

ETS was generated by concurrently and completely smoldering 8 cigarettes for each run. ETS is a complex mixture of solid and vapor phase particles produced primary from the burning of cigarette depends on puff rate [8]. The TP ETS sampler validation was focused on the deposition mechanism, thus smoldering cigarette smoke was effective and appropriate for these experiments. The TP ETS sampler controller microprocessor was programmed to switch amongst the 3 sampler TP wire regions in a reversing sequence fashion (i.e., 1-2-3, 3-2-1, 1-2-3,…) every 5 minutes. The purpose of this was to avoid collection bias during decay of the

aerosol concentration in the chamber, and therefore this non-random sampling pattern distributed near-equal particle mass collection on each of the three regions of the sampler's collection surfaces. A series of experiments were conducted at increasing wire voltage settings from the pre-set voltage of 1.0 V to the optimal voltage where a maximum particle collection value (see Table 1) was reached. The voltage and current inputs of each wire were recorded for analysis. Each experiment was allowed to collect for at least 17 hours in order to obtain significant amount of ETS.

v. Spectrometry and Related Statistics

The samples on the glass slide collection surface were then examined by using fiber optic probes connected to a UV-NIR spectrometer (Ocean Optics, Dunedin, FL, S2000 UV-VIS 250-800nm). Figure 2 shows the schematic of the operation when the UV LED was powered. The LEDs were placed on a light-tight housing and connected to an external power supply. With the LEDs turned on, UV or NIR light was transmitted through the cover slide. Fiber optic probes were attached to the bottom of the housing cavity and connected via a channel selector to the spectrometer. After ETS was collected on the glass cover slide the sample spectrum was recorded. Next, the ETS sample was removed by cleaning off the glass collection surface to obtain the baseline spectrum. The absorbance was calculated with Beer's Law, $A = -\log(I/I_o)$, where I and I_o were the calculated peak intensities of the spectrum taken by a spectrometer.

To account for small differences between ETS concentrations in each experiment, the calculated ETS absorbance was normalized by the integrated ETS concentration from the PEM during the sampling period in order to determine collection efficiency in terms of mass. The UV absorbance results were much more robust than those from the NIR LED since ETS has strongly enhanced UV absorbance. The NIR absorbance measurements in the case of these ETS samples

were typically below the limit of quantitation for the method, making them of little use in this investigation. The filter mass collected by PEM Teflon-coated fiberglass filter was first measured with an electronic microbalance, and then the air PM concentration was calculated based on the sampling flow rate and duration. The ETS mass that entered the TP ETS sampler during each experiment was computed by multiplying the PEM-based PM concentration by the experiment sampling time and sampler flow rate. The TP ETS sampler UV absorbance was normalized to that of a 10 μg mass sampling based on the above calculation.

3. RESULTS

i. Collection Ratio

The Brock-Talbot deposition ratio was plotted as a function of aerosol diameter for NaCl in Figure 3*a*. Figure 3*b* depicts the influence of the thermal conductivity of different materials on thermophoretic deposition. Table 2 lists the thermal conductivity ratio (k_p/k_a) of several possible material types that can be found in PM. These results taken together show how the different types of PM could have different thermal properties that affect the TP collection ratio. Figure 3*a* shows that the thermophoretic particle deposition ratio is about 0.6 and gradually decreases to 0.1 for the pre-set thermal gradient (∇T=1600 K/cm), from 10 nm to about 1 micrometer.

ii. Temperature Correlation

Heating the TP wires inside the oven generated resistance vs. temperature data that matched well with the wire manufacturer's temperature coefficient of resistance (see the dashed line in Figure 4*a*). The voltage applied to the TP wire during sampling was recorded each time, and the correlation to resistance was plotted (Figure 4*b*). Thus comparing Figure 4*a* to the former graph one can obtain the temperature as a function of applied voltage. Combining the fitted

equation from Figure 4*b*, and the theoretical curve from 4*a*, a relationship could be simply described as T = 145.1V - 28.5, where T is the TP wire temperature (°C) forming the thermal gradient and V is the applied voltage. Table 1 summarizes the experimental applied voltages and their thermal parameters.

iii. Normalized Absorbance and Optimal Collection

The chamber experiment data show increased particle collection in terms of absorbance with increasing wire voltage. ETS absorbance measurements from the TP ETS sampler normalized to a 10 μg sample was plotted against TP wire voltage and fitted with a 2nd order polynomial (see Figure 5). Each data point was obtained by averaging two experiments. Error bars in Figure 5 represent the greatest deviation from the experimental average. The optimal voltage for this ETS sampler was identified between 2.5 and 3.0 V, based on this fit.

4. DISCUSSION AND CONCLUSION

Thermophoretic modeling (Figure 3*a*) shows effective collection ratio for sub-micron particles. Here, the collection ratio is defined as the ratio of TP velocity to the mean air velocity in the channel, and the collection efficiency is the ratio of aerosol being collected to the amount that flows in the channel. As a remark, Reference [5] called the quantity η, the collection efficiency and multiplied by 100%, and Reference [9] also called it the collection efficiency yet left it as decimal number. In this chart, the particle collection ratio quickly decreased in the micron region. As the diameter increases further (Kn<2), the collection decreases drastically to 0.1. The Brock-Talbot simulation explains that particle deposition will increase substantially as the thermal gradient is raised above ∇T=1600 K/cm, a value that was previously set for this device. If the ratio k_p/k_a is small, the diameter of the particle determines the value of Equation (3)

with C_t Kn term dominates; on the other hand, with k_p/k_a increasing the collection ratio decreases drastically as seen in Figure 3*b*. This result is consistent with the presentation by Hinds on the subject of thermophoretic velocity as a function of k_p/k_a [3].

Based on the Brock-Talbot's theoretical prediction, we should expect higher particle deposition for sub-micron sized particles. The calculated thermal gradient for 2.5 V is about ∇T=6090 K/cm, and the Brock-Talbot model collection ratio for this thermal gradient is well above 1.0. The original selection for TP voltage of this low-cost particle sampler took into account the power consumption; 1.0 V TP voltage was believed to be above 80% efficient for PM-2.5 collection according He and Ahmadi's results [5, Figure 9]. This study has shown, both numerically and experimentally, the optimal deposition ratio occurs between 2.5 and 3.0 V for this TP ETS sampler. The absorbance at 2.5V TP collection shows a signal five times stronger than that of 1.0 V (Figure 5). It is obvious that the optimal collection efficiency in term of normalized ETS mass at least factor of 5 higher than the 1V thermal gradient. Figure 6 shows another relationship of deposition ratio, this verified the Brock-Talbot model also predicted an enchantment of a factor of 5 (from about 0.5 to 2.5 for a 100nm particle diamter). This result may provide a useful calibration mechanism for developing the TP ETS sampler.

5. FUTURE WORK

This project investigated several major issues dealing with the TP ETS sampler particle collection efficiency and identified some important thermal parameters that influence aerosol collection by thermophoresis. This result raised a concern that the oven-treated TP wire temperature may not correctly describe the thermal gradient of the TP ETS Sampler's in-situ performance. Calibrating the sampler's thermal gradient will be helpful because the

configuration of TP wires relative to a cool flat collection surface differs from the two-parallel plate configuration used in the Brock-Talbot model [7, 9]. We have shown that the applied voltage for the TP wires should be higher. Moreover, how the TP wire temperature affects the thermal gradient is unsolved for the configuration of this sampler. This question can be answered with future investigation.

6. ACKNOWLEDGEMENTS

This work was supported by the Center for Science and Engineering Education at Lawrence Berkeley National Laboratory, Department of Energy, Office of Science, the California Tobacco Related Disease Research Program and the California Air Resources Board Innovative Clean Air Technologies Program. I would like to thank my mentors Michael Apte and Lara Gundel. I would also like to thank Matt McHugh, David Liederman, Rachelle Majeske, and Howdy Goudey for their assistance.

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FIGURES

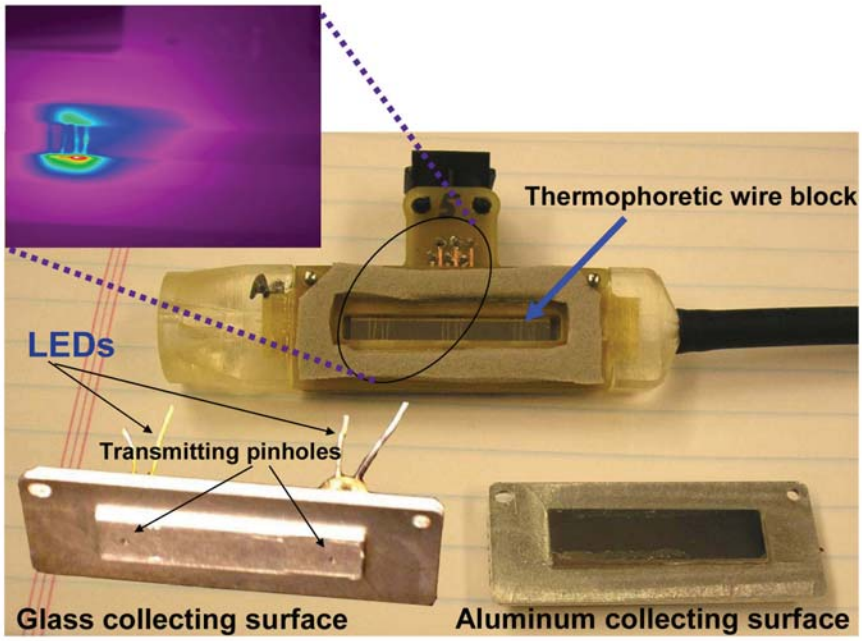


Figure 1: The TP ETS Sampler with thermophoretic wires indicated; glass collecting surface and aluminum collecting surface are separately shown at the left and the right. The thermogram insert shows the heated TP wires region when powered.

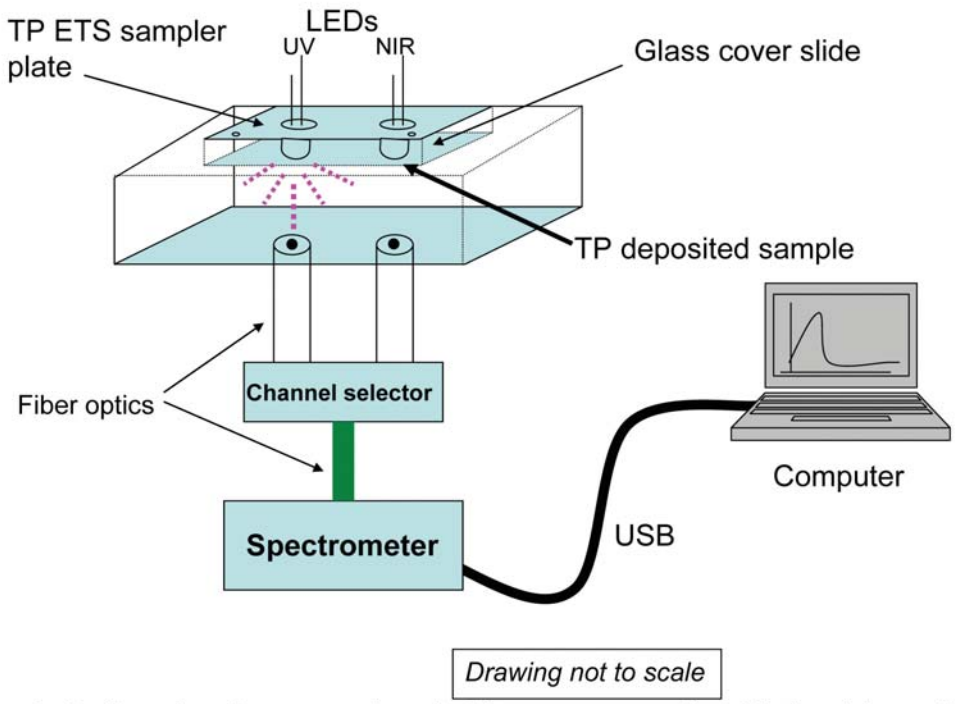
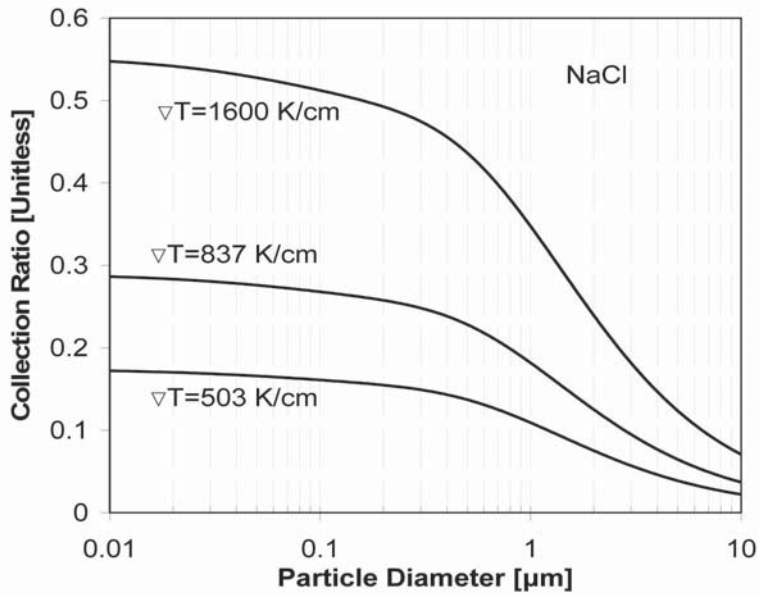


Figure 2: Configuration of spectrometric method for measurement of particle deposition on TP ETS Sampler.

(a)



(b)

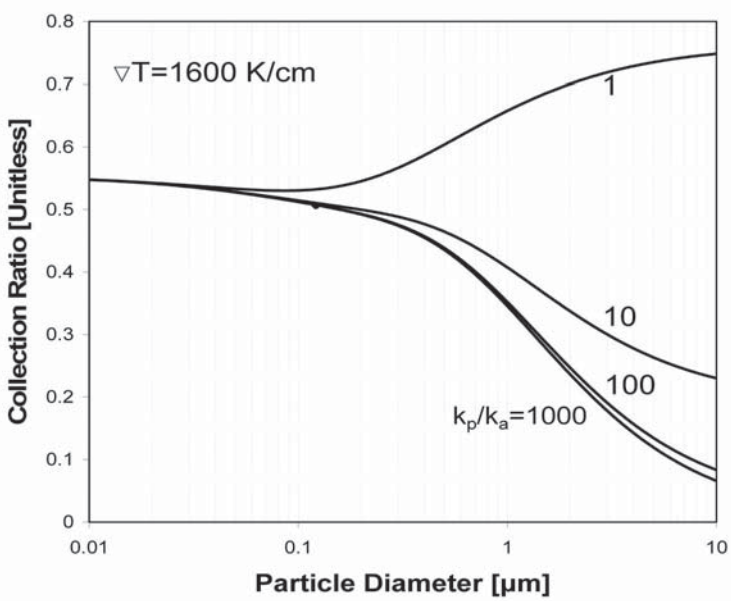
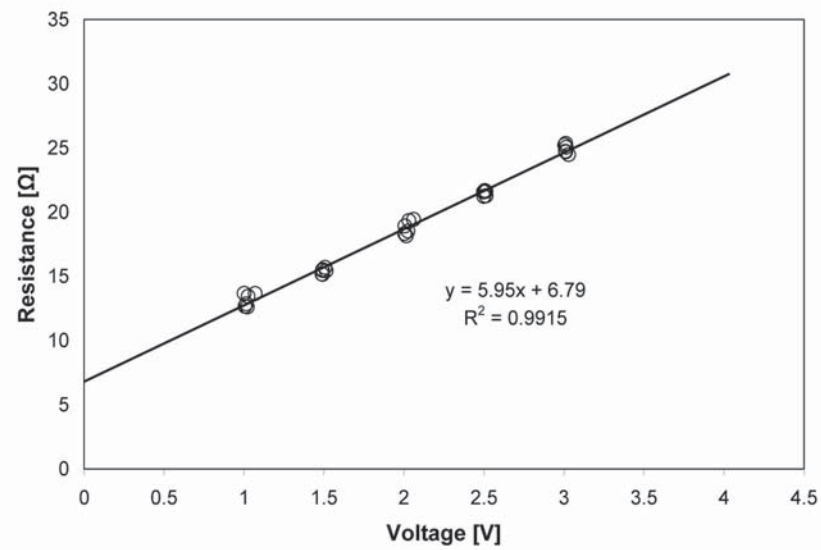


Figure 3: (a). Thermophoretic collection ratio vs. particle diameter using Brock-Talbot model with 3 different thermal gradients. (b). Particle collection ratio vs. diameter for different k_p/k_a using the Brock-Talbot model.

(a)



(b)

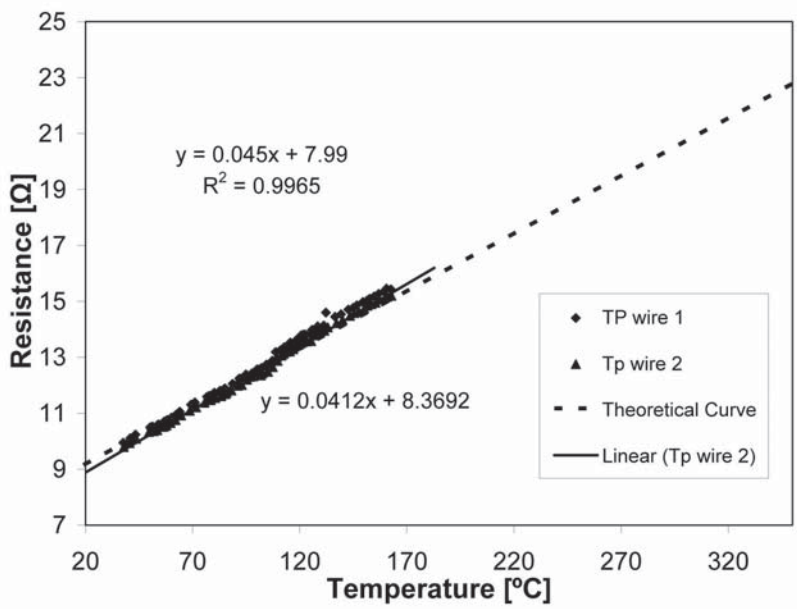


Figure 4: (a). Ten sets of applied TP voltages vs. resistance recorded from chamber experiments, with some of them coincide almost exactly. (b). Two different blocks of wire were heated and their resistances were measured. The dashed line is the curve calculated with manufacture resistance coefficient, α=0.0045, plotted for a wider range than the experimental range.

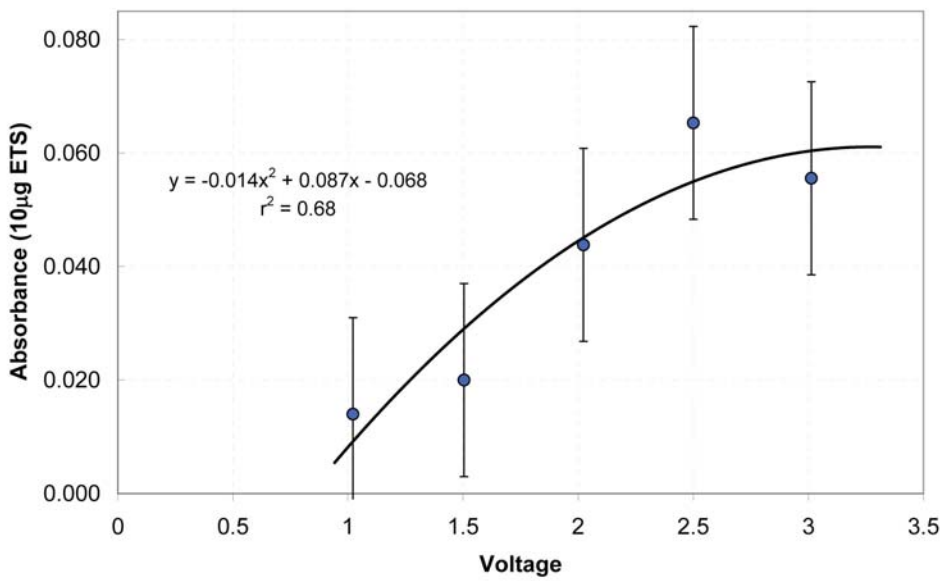


Figure 5: Particle phase titration result shows the optimal collection of the TP ETS sampler is with the input voltage of about 2.5 V; the scattered absorbance data are averaged with two filter mass (PEM) normalized data. Enchantment also suggested a factor of 5 better in collections. The error bars represent the greatest deviation from the experimental average based on two experiments for each voltage.

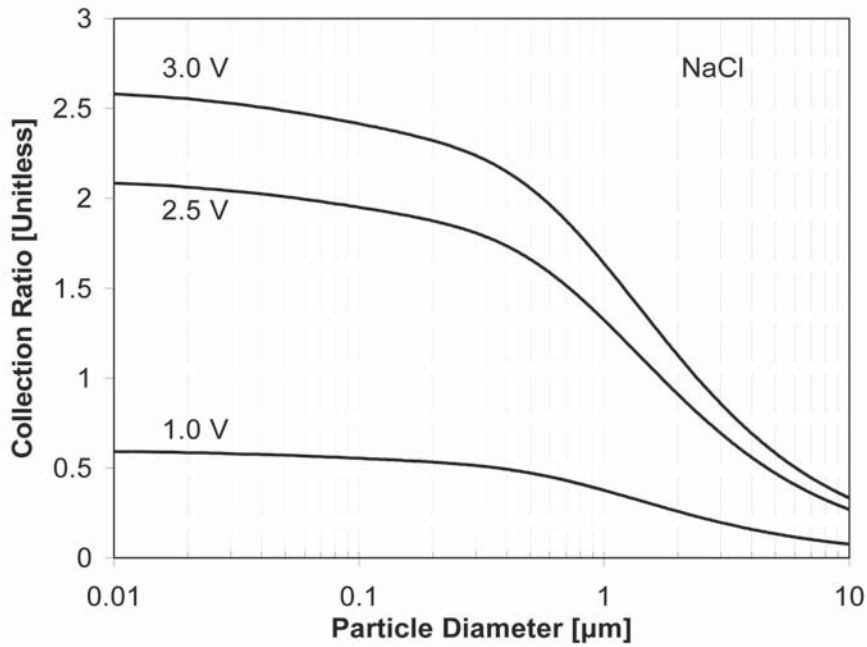


Figure 6: The Brock-Talbot model with thermal gradient corresponding to 1.0 (∇T = 1740 K/cm) , 2.5 (∇T = 6090 K/cm), and 3.0 V (∇T = 7540 K/cm) applied voltage (TP gradient). Result shows that 3.0 V applied voltage can collect a factor of 5 more than that of 1.0 V applied voltage.

TABLES:

TP Voltage and Related Thermal Parameters			
TP Voltage [V]	Resistance [Ω]	T [ºC]	∇T [K/cm]
1.0	13.6	107	1740
1.5	15.4	179	5190
2.0	18.3	252	4640
2.5	19.5	325	6090
3.0	25.2	397	7540

Table 1: The corresponding thermal parameters of the TP voltages used for experiments.

Thermal Conductivity Ratio (k_p/k_a) of Several Materials	
Materials	Unitless ***kp/ka***
Air at 20 ºC	1
Asbestos	3
Paraffin oil	5
Magnesium oxide	5
Stearic acid	5
Castor oil	7
Water	23
Clay	27
Glass	32
Fused silica	38
Granite	81
Carbon	169
Sodium chloride	254
Mercury	323
Quartz	369
Iron	2573

Table 2: Ratio of thermal conductivity of several materials to of air can be found in ambient air. k_p and k_a values were adopted from Ref. 3.

Sample Alternative Abstract

ABSTRACT

DNA Dilemma: A Perspective on Current USPTO Philosophy Concerning Life Patents. KALE FRANZ (Colorado School of Mines, Golden, CO 80401) PETER FALETRA (Office of Science, DOE Headquarters, Washington, DC 20585).

The lack of a solid set of criteria for determining patentability of subject matter—particularly subject matter dealing with life—has recently been of increasing public concern in the United States. Alarm for patent practices related to life systems ranges from patents being granted on biochemical processes and the knowledge of these processes to the patenting of entire organisms. One of the most volatile concerns is the patenting of human genes or parts of genes since this genetic material is the basic informational molecule for all life. Current patent law, legislated in 1952, has been interpreted by the U.S. Supreme Court to allow broad patents of DNA, biochemical processes, and what are generally considered "inventions" of life systems. Several issues are addressed in this paper regarding the unsound reasoning underlying both the interpretation and execution of patent law. Lapses in logic provide a gateway for businesses and individuals to take patenting to an illogical and unworkable extreme. Patent Office disorder of this magnitude is unnecessary and has great potential for harming the mission that the patent office was designed to serve. Recently disclosed patent-granting guidelines suggest the United States Patent and Trademark Office is not upholding its Constitutional responsibility of promoting the progress of science.

Sample Alternative Paper

"Living organisms are able to reproduce themselves even if they are patented, and in view of this special quality of living organisms, the scope of a patent is difficult to define, which makes it nearly impossible to find a balance between private and public interests" [1].

INTRODUCTION

Patents on life, ranging from DNA fragments to entire organisms, have reached mainstream concern in the past few decades. It is now obvious that several fundamental problems exist with United States patent law and the system that has been established to execute that law. Through the United States Patent and Trademark Office's interpretation of Supreme Court decisions[2], patents on DNA have been deemed grantable. As this paper illustrates, it is now theoretically possible to acquire a patent on any life-related subject matter, whether the subject matter is in essence a duplication of nature or otherwise. Through the current practice of granting life patents, fundamental problems arise because of the distinct differences that exist between life and inanimate objects. At this time, the patent system needs to undergo a significant reevaluation to ensure that it is promoting the best interest of science in a sound and logical manner.

The magnitude of the current challenges facing the patent office is easily seen in the number of pending genetically related patents. Through the end of December 2000, approximately 25,000 DNA-based patents were granted [2]. Several forms of life-related subject matter have been successfully patented: Expressed Sequence Tags (EST), which serve as gene markers along a DNA strand; Single Nucleotide Polymorphisms (SNP), which are single-base variations within DNA that could potentially cause disease; and regulatory sequences—all only gene fragments—have been patented [3]. Entire genes, such as a gene called CCR5 that helps in the process of allowing HIV entrance into immune cells, have also been patented. An entire chromosome of a vertebrate is yet to be patented [4].

LEGAL JUSTIFICATION FOR DNA PATENTING

To obtain a patent on DNA of any type or scope, the DNA fragment must be isolated and purified from its (thus far) observed natural state, or the fragment must be produced in purified form in a laboratory. More specifically, the following eligibility conditions as stated in the United States

Patent and Trademark Office (USPTO) Utility Examination Guidelines, must be met:

> an excised gene is eligible for a patent as a composition of matter or as an article of manufacture because that DNA molecule does not occur in that isolated form in nature, or (2) synthetic DNA preparations are eligible for patents because their purified state is different from the naturally occurring compound. [5]

Thus, it is not acceptable to patent the exact genes as they exist in an individual [6]. However, several other logical conflicts and practical dilemmas arise from this patent philosophy.

As Condition (1) infers, one method by which DNA patents can be acquired is through patenting DNA that has been extracted from its natural environment. Since DNA is patentable, and by its very nature is part of all living organisms, any organism should be patentable by a similar mechanism to that established for the patenting of DNA. This brings about startling possibilities, the consequences of which the USPTO may have never anticipated or desired.

Entire organisms like plants, bacteria, even mice, have indeed been patented. All such patents, however, have been of an entirely different nature than DNA patents. These organisms have been fundamentally changed in some way by human ingenuity to improve upon their previous functions, abilities, and characteristics. Bacteria were genetically altered for oil-spill bioremediation purposes [7]; numerous plants have been transgenically altered for production purposes and other specific qualities [8]; mice are commonly genetically engineered as in the case of the "knockout" mice [9]: patents have been granted in all of these situations. The purification and isolation of DNA does not resemble such accomplishments. Patented DNA has simply been stripped of some of the critical parts it needs to function in a natural setting, but the base code still remains intact and unchanged by human influence.

CONDITION (1): PATENTING A TREE

Let us now consider patenting a tree by the same process that one would undertake to patent a DNA fragment under the first USPTO-defined condition. Though patenting a tree at first seems completely absurd, it is quite conceivable given current patent law and USPTO guidelines. While attempting to satisfy the requirements for patent approval legislated by Congress and interpreted by

the USPTO in its execution of that legislation, the *Metasequoia glyptostroboides*—long thought extinct—will serve as our hypothetical example, though someone has yet to apply for a patent on this tree or any tree by such means. Several criteria need to be met in order to obtain a patent on *Metasequoia*. Formally, these criteria consist of non-obviousness, novelty, utility, and enablement. The first criterion however, and perhaps most logically troublesome, is that the tree must be an invention of human design. At first thought most individuals would believe it impossible for humans to invent the *Metasequoia*; it has already been created by nature. But the USPTO has a different view and exercises its duties accordingly. Patent law states that:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title. [10]

Just as DNA must be removed (purified and isolated) from the environment in which it has been observed, so too must the tree. To "invent" the *Metasequoia* we simply need to take it from central China and plant it in our own backyard. As an extra measure, we will thoroughly clean the tree so that none of the native dirt is attached to its roots, no naturally growing fungi or bacteria indigenous to the region are residing on the tree, and all other foreign material such as birds and their nests are free from the tree's limbs. *Metasequoia* has now been isolated and purified and thus is our own "invention."

The tree must be non-obvious, which is defined by the USPTO to mean that the claimed subject matter must not be obvious to a person of ordinary skill in light of what was previously known [11]. Since *Metasequoia* was thought to be extinct, its existence on Earth today was not common knowledge to those of ordinary skill in the field of botany. Given this, *Metasequoia* would also conform to the novelty requirement as well, which states that a patent cannot be granted for an entity that has already been invented by someone else [12]. While no human invented the tree as it existed in nature, and because we invented the tree as it exists outside of nature, the novelty requirement is satisfied.

Metasequoia must have utility [13]. In other words, it must be useful in at least one way. "The patentee is required to disclose only one utility, that is, teach others how to use the invention in

at least one way" [14]. *Metasequoia*, as in the nature of all trees, is useful in any of a number of applications. Thus, our tree fits perfectly with the utility requirement. To meet the final requirement, our *Metasequoia* patent must show enablement.

> The specification shall contain a written description of the invention, and of the manner and process of making and using it…to enable any person skilled in the art to which it pertains…to make and use the same. [15]

To satisfy this requirement, we must simply describe in what fashion the tree was transplanted from its native land to our backyard as well as how to use it to benefit from the previously described utility.

CONDITION (2): PATENTING A PROTON

As formerly alluded to, the second condition—Condition (2)—that makes DNA eligible for patenting is satisfied after the DNA has been "synthesized in a laboratory from chemical starting materials" [16]. Hence, biologists must simply prove that they can recreate in a laboratory setting that which has already been created by nature. If patenting practices of this form are adopted by other science disciplines, perplexing and possibly undesirable consequences could result. For example, ever since Einstein proposed his famous equation $E = mc^2$, a result of the Special Theory of Relativity, it has been understood that all matter is simply a form of energy [17]. Today, scientists have the ability to manipulate energy in the vast number of particle accelerators that exist all over the world to create the various elementary particles of nature [18]—particles as common as the proton and as exotic as the Z boson. If DNA can be patented simply by synthetically creating it from more basic materials and meeting the four other conditions and requirements outlined by patent law, a proton or Z boson should theoretically be patentable because it can likewise be created. The ramifications of such patents being granted are incomprehensible.

THE DENIAL OF EXAMPLE PATENT APPLICATION IDEAS

Would the patent office ever grant a patent on *Metasequoia* or a proton in the manner that has been suggested, even though the application would comply with all of the outlined requirements in

the same way DNA patent applications do? Since the patent office has yet to encounter a patent on a tree or a proton, one can only speculate upon the outcome. It inherently seems absurd to any rational person for a patent to be granted on a tree. In all probability, the patent office would reject a patent application on a tree not because of the apparent absurdity, but because of the size scale on which the patent is being proposed. The USPTO would likely not see the isolation and purification process used with *Metasequoia* as comparable to the isolation and purification that is undergone with DNA. The isolation and purification of the tree as described above is a fully tangible and visually understandable process, unlike the isolation and purification of DNA, which by its technical nature is more abstract. This dichotomy would almost certainly be enough to sway the patent office's view on the purification of the tree and thus reject the patent for not meeting the standard criteria. With the application of simple logic one can see that purification processes differing in physical size and technological scale can otherwise be quite similar. Given this, the USPTO seems to unwittingly hold a standard for patentability based on size and technological level.

Such a patent system based ultimately on size is inherently ambiguous. Size, like most any continuous system, presents natural difficulties when trying to establish arbitrary boundaries within the system. At what size does an object move from the non-patentable realm into the patentable? If DNA is patentable, then is an entire cell patentable? If an entire cell is patentable, then certainly a free-living, single-celled organism would be patentable material. If a single celled organism is patentable, then why not a multi-celled organism? Though, as mentioned earlier, patents have been granted on multi-celled organisms, all patented organisms have, to this day, been in some way genetically altered by humans and not simply the product of nature.

Similarly, it would probably be considered equally absurd to grant a patent on the proton. Protons are basic building blocks of all matter. But it follows that DNA is a basic structure of all life. For DNA to be patentable, all entities on Earth, whether devised by the creativity of humans or otherwise, must be in essence patentable. This certainly defies Congress's original intention when writing current patent law in 1952 that "anything under the sun that is *made by man*" [19] (emphasis added) be patentable subject matter.

PLAGIARIZING NATURE'S WORK

Another fundamental problem exists with the patenting of DNA. Historically, patents have been granted for inventions of an original mechanical nature or process. Plows, automobiles, and oil refinement processes have all been patented. More recently, computer chip designs and biological processes such as the polymerase chain reaction have been patented. Those patents are intrinsically different from patents on DNA fragments since they are processes or creations of humanity and not extant physical entities in nature.

Traditional patents encourage further innovation and ingenuity because it is physically possible to *invent around* the patented subject matter with a new and novel idea. However, DNA was not a human innovation, but a manifestation of nature that has undergone millions of years of evolution. By purifying and isolating DNA to patent it, humans are simply plagiarizing nature's work. Because of the innate characterisIn this regard the USPTO seems confused. The USPTO likens DNA patenting to patents on television sets and the picture tubes therein, as explained by the USPTO Director of Biotechnology Examination.

> "The USPTO views this situation as analogous to having a patent on a picture tube. The picture tube patent does not preclude someone else from obtaining a patent on a television set. However, the holder of the picture tube patent could sue the television set makers for patent infringement if they use the patented picture tube without obtaining a license." [20]

A dissection of this analogy is revealing. A Single Nucleotide Polymorphism (SNP) would be analogous to the picture tube, and a cure for a disease is analogous to the television set. Consequently an SNP patent does not preclude someone else from obtaining a patent on a cure for a disease, which is attributable to that SNP. However, the holder of the SNP patent could sue the "disease-cure" manufacturer for patent infringement if that manufacturer uses the patented SNP without obtaining a license.

The USPTO analogy is confusing, though a simple conclusion results. It is entirely possible for the television set maker to choose any of a number of picture tubes that have already been patented to use in a television set. More importantly, the television set maker can opt to design its own picture tube because it is physically possible to invent around patented picture tube innovations. Conversely, a competitor of the "inventor" of the SNP cannot pick and choose among other SNPs for

a cure for the same disease since the originally patented SNP was the natural cause for that disease. Furthermore, DNA is wholly unique to this planet not because of human invention and action, but because of the forces that allowed it to evolve. Inventing around DNA therefore is entirely impossible without redesigning billions of years of evolution and "remaking" life systems altogether.

THE ROLE OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

In addition to current patent guidelines seeming illogical, strong potential exists for the hindrance of the advancement of science and engineering innovation. The United States Constitution provides:

> The Congress shall have Power…To promote the Progress of Science and useful Arts, by securing for limited Times to Authors, and Inventors the exclusive Right to their respective Writings and Discoveries. [21]

The USPTO was established to execute this Constitutional mandate. Keen observers may deduce that it is the current position of the USPTO to interpret this statement with emphasis on "securing for limited Times…exclusive Right to…Discoveries." However, the purpose of the patent office is not to simply impart patents without regard for the objectives it was created to serve. The USPTO should take special care to fulfill its first and foremost duty, which is "To promote the Progress of Science and useful Arts." Strong economic and scientific advancement arguments exist on both sides of the DNA patenting issue; individuals in the scientific, academic, research, economic, and law communities are heavily divided. Through all of the controversy, it appears that the patent office is not seeking the avenue that will truly yield the most success for accomplishing its purpose, but is simply upholding previously established patent precedent. The USPTO should be more forthright about fighting to uphold its constitutional obligation of promoting the state of science. Even though "it is a long tradition in the United States that discoveries from nature which are transformed into new and useful products are eligible for patents," [22] precedent should not supersede purpose.

That the patent woes of other nations might be just as daunting as those of the United States was recently illustrated by John Keogh who successfully applied for and received a patent in Australia for…the wheel. He does not expect to make money from the patent but did receive worldwide

attention and the 2001 Ig Nobel Award in Technology [23].

ACKNOWLEDGEMENTS

This research was conducted at the U. S. Department of Energy Headquarters. I would like to take this opportunity to express my sincere gratitude to my mentor Peter Faletra. He has been an inspiration and has given me a great deal of direction and desire to continue my ongoing pursuit of science. I would also like to thank Cindy Musick and Sue Ellen Walbridge for all of the support and guidance they have given me throughout my internship. Additionally, I would like to thank the Department of Energy, the Office of Science, and the SULI Program for allowing me the opportunity to participate in such an exceptional and fulfilling internship program.

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[22] Utility Examination Guidelines, 66 Fed. Reg. 1,093 (2001)

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Note: These references are not necessarily formatted in IEEE style because the IEEE citation format is not designed for legal citations and is thus silent on the format for several legal sources.

Sample Poster

Title Slide

Characterization of the Microbial Community in a Methane-Driven Denitrifying Bioreactor

Ana C Fernandez,
William Stringfellow, Gary Andersen

United States Department of Energy

University of Florida

Gainesville, FL 32611

Abstract Slide

Abstract

Lawrence Berkeley National Laboratory

Denitrification is an important step of the wastewater bioremediation process. It involves the removal of nitrogenous compounds from wastewater, known to cause adverse effects to human health and the environment. Because denitrification is the last step in the wastewater bioremediation process, a supplemental source of organic carbon must be added at a significant cost to wastewater treatment plants. Methane may be an inexpensive alternative source of organic carbon for denitrification. Previous studies suggest that coupled anaerobic methane oxidation and denitrification may be an effective, low cost alternative to facilitate the denitrification process in wastewater treatment plants. Understanding the microbial community present in a coupled anaerobic methane oxidation denitrifying system may allow for optimization of denitrification in wastewater treatment facilities. In this study, a low oxygen, methane-oxidizing denitrifying bioreactor (MOR) is used to emulate a coupled anaerobic methane oxidation denitrifying system. Methanotrophic and denitrifying bacteria are expected to be the major constituents of the MOR. 16S rDNA sequencing via microarray hybridization is used to identify the microbial community of the MOR. Results show that five bacterial subgroups represent the major constituents of the microbial community of the MOR, including members of the *Bacillus* subdivision known to reduce nitrate to nitrite. Denitrifying bacteria are indeed the major constituents of the microbial community of the MOR. However, 16S rDNA microarray technology is unable to detect the presence of known methanotrophic bacteria in the MOR. The 16S rDNA microarray must be optimized to detect methanotrophic bacteria. Additionally, the microarray technology is used to identify the microbial communities of an ammonia-oxidizing bioreactor (AOR) and a hydrogen membrane bioreactor (HMBR). As expected, distinct microbial communities are found in each of the three bioreactors using the 16S rDNA microarray. Results show that the 16S rDNA microarray is effective for the identification of distinct microbial communities in different bioreactors.

Introduction and Hypothesis Slides

Objectives

Lawrence Berkeley National Laboratory

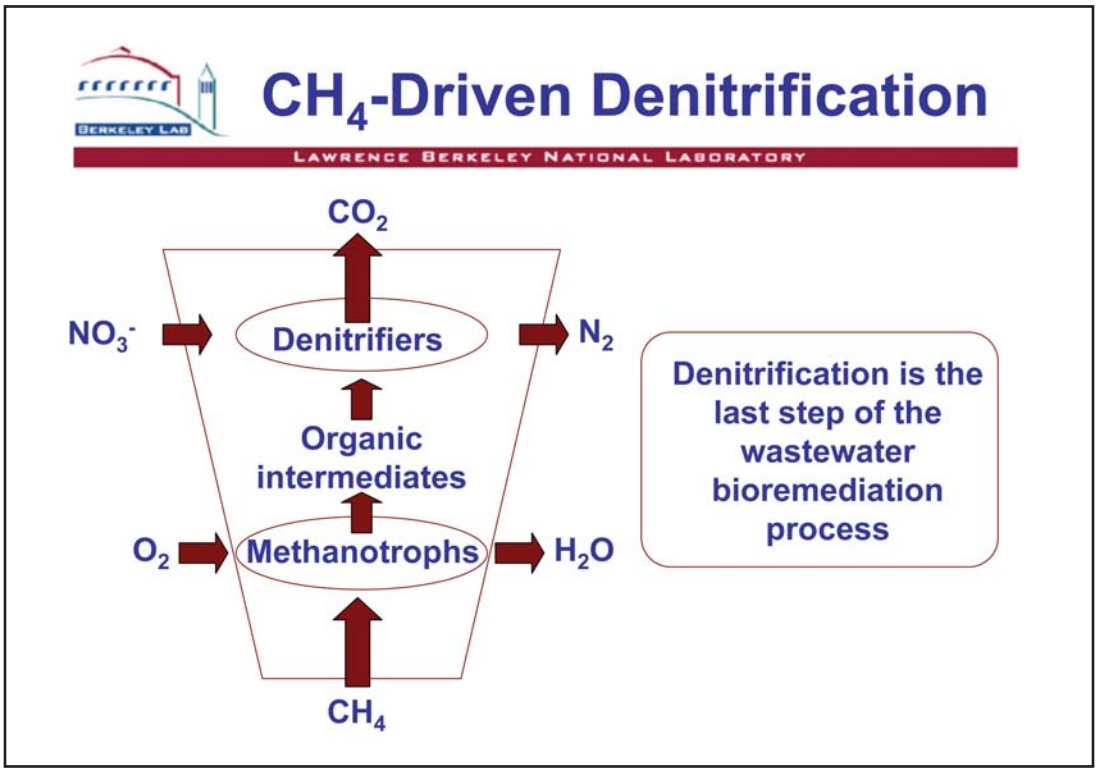
1. To characterize the microbial community in a methane-driven denitrifying bioreactor (MOR) using 16S rDNA sequencing via microarray hybridization
2. To determine the effectiveness of the 16S rDNA microarray for the identification of the microbial communities of three distinct bioreactors

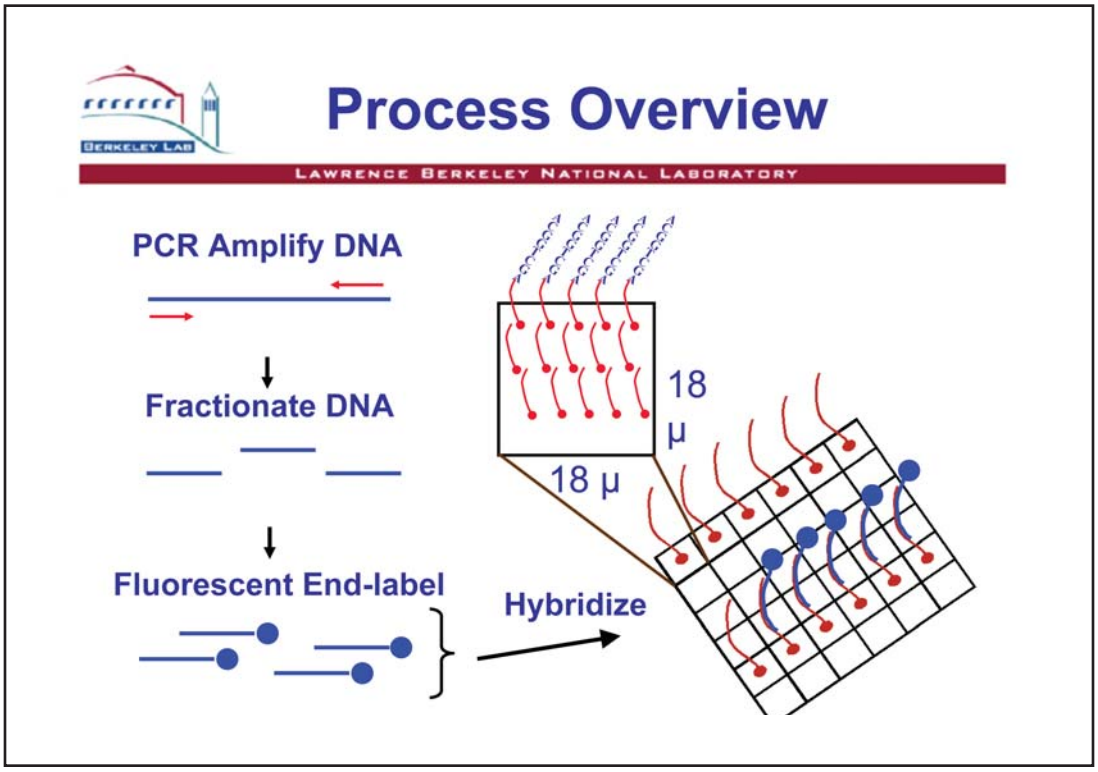
Hypotheses

Lawrence Berkeley National Laboratory

1. The microbial community in the methane-driven denitrifying bioreactor (MOR) is primarily composed of methanotrophic and denitrifying bacteria
2. Each of the different bioreactors has a distinct microbial community that is related to its function

Methods and Materials Slides

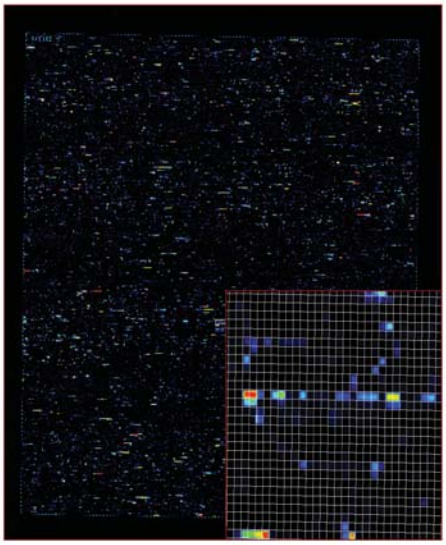




Microarray Analysis

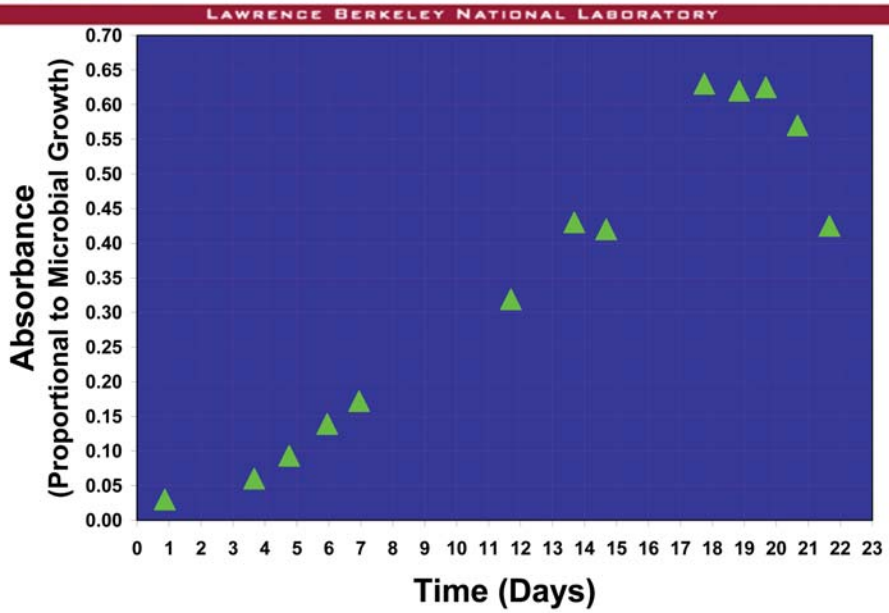
LAWRENCE BERKELEY NATIONAL LABORATORY

- 500,000 probes designed to match 9,900 target 16S rDNA sequences
- Fluorescence upon probe-target match indicating positive ID of a species



Microbial Growth in MOR

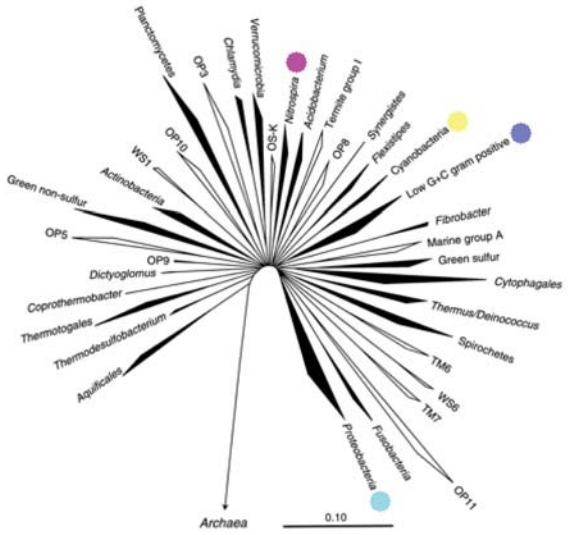
LAWRENCE BERKELEY NATIONAL LABORATORY



Results Slides

Bacterial Kingdom Diversity

LAWRENCE BERKELEY NATIONAL LABORATORY



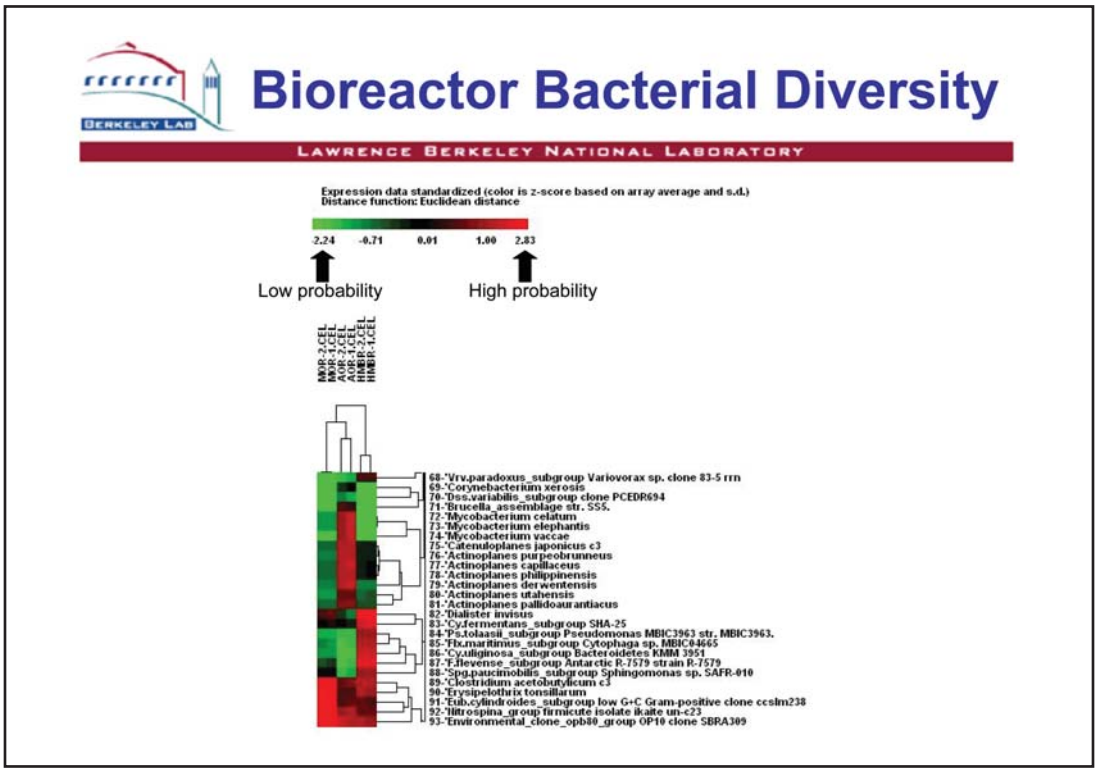
Major Bioreactor Constituents

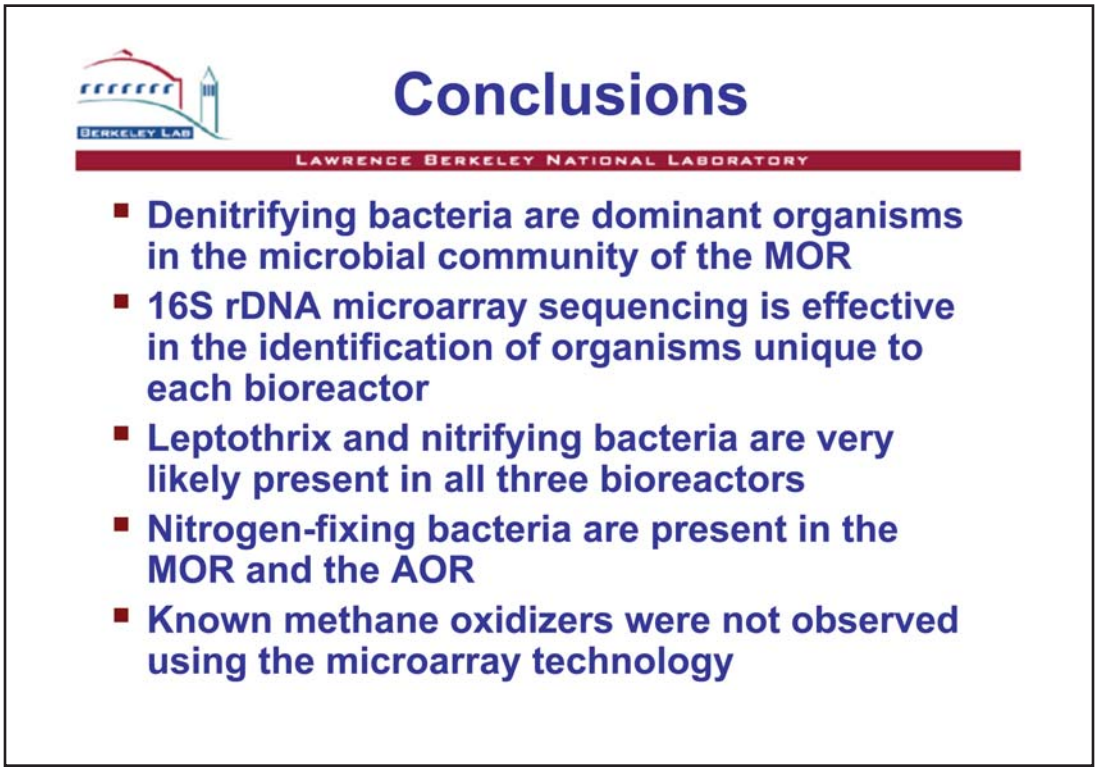
LAWRENCE BERKELEY NATIONAL LABORATORY

Bacterial Phylogeny	Relation to Bioreactor Function	Bioreactors: Methane-Oxidizing	Ammonia-Oxidizing	Hydrogen Membrane
B.ALCALOPHILUS_SUBGROUP (2.30.7.9.3) Sporolactobacilus_Group Bacillus-Lactobacillus-Streptococcus_Subdivision Gram positive Bacteria	*Bacillus* -reduces nitrate to nitrite under anaerobic conditions	X		
STC.PNEUMONIAE_SUBGROUP (2.30.7.21.9) Streptococci Bacillus-Lactobacillus-Streptococcus_Subdivision Gram positive Bacteria	*Bacillus* -reduces nitrate to nitrite under anaerobic conditions, *Streptococci* -fermentative aerotolerant anaerobe	X		
LPTX.DISCOPHORA_SUBGROUP (2.28.2.9.5.4) Leptothrix_Subgroup Acidivorax_Group Beta_Subdivision Proteobacteria	*Leptothrix* -sheathed bacteria common in freshwater habitats that are rich in organic matter	X	X	X
ENVIRONMENTAL_CLONE_III1-8_GROUP (2.13.6) Nitrospina_Subdivision	*Nitrospina* -oxidize nitrite to nitrate, chemolithotrophic bacteria involved in nitrogen cycling in marine waters	X	*	X
CHLOROPLASTS_AND_CYANELLES (2.21.2) Chloroplasts and cyanelles Cyanobacteria and chloroplasts	*Cyanobacteria* -principal nitrogen fixers, oxygenic photothrophs	X		X

X indicates presence of bacteria in bioreactor
*** indicates one of the replicates is slightly below the positive fraction cutoff**

Discussion and Conclusions Slides





Future Work

LAWRENCE BERKELEY NATIONAL LABORATORY

- Monitor nitrate consumption/nitrogen gas production in MOR
- Track methane consumption/organic carbon production in MOR
- Optimize microarray technology for the detection of methane oxidizers
- Study the effects of time on microbial community development
- Determine limiting substrates for microbial community development

Acknowledgements/References Slides

Acknowledgements

LAWRENCE BERKELEY NATIONAL LABORATORY

- United States Department of Energy
- Lawrence Berkeley National Laboratory
- Center for Environmental Biotechnology
- Andersen Group
- Stringfellow Group

Sample Educational Module

COMPLETE SAMPLE EDUCATIONAL MODULE

TITLE

Bacteria: The good, the bad, and the ugly (including the theory of Endosymbiosis)

AUTHOR

Sarah Whitaker

GRADE LEVEL/ SUBJECT

General Biology
Grades 9, 10, and 11
90 minutes, 7 days total

CURRICULUM STANDARDS: NSES

Life Science

CONTENT STANDARD C: As a result of their activities in grades 9-12, all students should develop understanding of:

Biological Evolution

- The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.
- Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.
- The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors.
- Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

The Interdependence Of Organisms

- Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. This fundamental tension has profound effects on the interactions between organisms.

Earth and Space Science

CONTENT STANDARD D: As a result of their activities in grades 9-12, all students should develop an understanding of:

The Origin And Evolution Of The Earth System

- Evidence for one-celled forms of life -- the bacteria -- extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen.

Science and Technology

CONTENT STANDARD E: As a result of activities in grades 9-12, all students should develop:

Understandings About Science And Technology

- Scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations. Many scientific investigations require the contributions of individuals from different disciplines, including engineering. New disciplines of science, such as geophysics and biochemistry often emerge at the interface of two older disciplines.
- Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.
- Science and technology are pursued for different purposes. Scientific inquiry is driven by the desire to understand the natural world, and technological design is driven by the need to meet human needs and solve human problems. Technology, by its nature, has a more direct effect on society than science because its purpose is to solve human problems, help humans adapt, and fulfill human aspirations. Technological solutions may create new problems. Science, by its nature, answers questions that may or may not directly influence humans. Sometimes scientific advances challenge people's beliefs and practical explanations concerning various aspects of the world.

OVERVIEW

This module contains activities such as word searches, games, Jeopardy style games, and a hand washing activity to spark a student's interest and their scientific inquiry as well as lab activities where the students learns to grow bacteria and what can kill them. It also includes some lecture time to make sure all the standards are thoroughly covered and the PowerPoint that was created to do this is included as well.

LEARNING OBJECTIVES

- Students will have a better understanding of bacteria and their processes.
- Students will have a better understanding of advanced theories like the theory of Endosymbiosis.
- Students will be able to trace back the evolution of the multicelled organisms to the single celled bacteria.
- Students will use the scientific inquiry to adequately make a hypothesis and a conclusion based on an experiment.
- Students will continue refining their lab reporting skills as well as their skills in keeping a lab notebook.

Time Allotted: 90 minutes, 7 days total

VOCABULARY

Bacteria	Coccus	Endosymbiosis
Bacillus	Spirillium	Aerobic
Diplococcus	Streptococcus	Anaerobic
Staphyococcus	Diplobacillus	Streptobacillus
Petri dish	Bacterial flagellum	Agar
Incubator	Capsule	Aseptic technique
Inoculation	Antiseptic	Disinfectants
Asexual reproduction	Carbolic Acid	Ethanol
Lag phase	Stationary Phase	Log phase

RESOURCES AND MATERIALS

- Textbook
- Notebook – Lab and classroom
- Microscope
- Prepared slides of Bacteria- some with the labels covered and some uncovered
- Petri dish with nutrient agar
- Incubator
- Sterile cotton swabs
- Pond water or other bacteria rich source
- Petri dishes that have a nutrient agar that has been treated with various pH solutions (pH= 2,4,7,8,10,12)
- Dark closet
- Incandescent lamp
- Fluorescent lamp
- Small, sterile paper discs
- Tweezers
- Bunsen burner
- Commercial disinfectant
- Commercial antiseptic
- Commercial antibacterial soap
- Carbolic acid
- Ethanol
- Ruler with mm measurements

PREREQUISITE KNOWLEDGE

The students should already know how to classify, to use all lab equipment, and write a lab report. They also need to have some basic evolutionary knowledge. They need to know what pH is and what it means.

MAIN ACTIVITIES

DAY 1 -- PRE-LAB QUESTION: (10-15 minutes)
The year is 2164 and you have discovered many new species of bacteria (Phylum Schizophyta). Your job is to classify these organisms. You may chose any classification system you want, as long as each organism can be placed somewhere in your classification system. Your observations are as follows:

some purple bacteria are triangular
some bacteria are yellow
some blue bacteria are shaped like ovals
some red, hexagonal bacteria are found in pairs
some purple, triangular bacteria are found in pairs
some yellow bacteria look like doughnuts
some bacteria are red
some purple bacteria are square
some blue bacteria are pentagonal
some yellow, spiral bacteria are found in triplets
some red bacteria are circular
some bacteria are purple
some purple, triangular bacteria are found in triplets
some bacteria are blue
some red bacteria are hexagonal
some yellow, doughnut-like bacteria are found in pairs
some red bacteria are rectangular
some purple, square bacteria are found alone
some yellow, doughnut-like bacteria are found in quartets
some purple, square bacteria are found in pairs
some red, circular bacteria are found alone
some purple, square bacteria are found in pairs
some red, circular bacteria are found in pairs
some yellow bacteria are spirals
some yellow, spiral bacteria are found in pairs

Produce a chart that clearly shows all of the new categories and sub-categories of bacteria. Be creative: for example, give neat names to each of your categories and sub-categories...BUT, these names should be related to their characteristics in some way!

Lecture: (15 minutes)

See attached outline.

Lab: (60 minutes)

Objectives: To introduce the students to the three major bacterial groups COCCUS,

BACILLUS, and SPIRILLUM. The students will observe representative bacteria from each of the subgroups of these three categories

Materials: microscope; prepared slides of bacteria (some labeled, some not)

Procedure:

1. The students are given a set of labeled slides of bacteria. There should be one slide from each of the major subgroups of bacteria:

Coccus	Bacillus
diplo-coccus	diplo-bacillus
streptococcus	strepto-bacillus
staphylococcus	
Spirillum	

2. For each of the subgroups of bacteria, the students will draw a labeled diagram of the type of bacteria including the name of the specimen and the magnification.

3. The students will also prepare a chart showing the main categories and their subgroups with a written definition for each, for example:

Main Group	Subgroup	Description
COCCUS		- spherical bacteria
COCCUS	DIPLOCOCCUS	- spherical bacteria, found in pairs
COCCUS	STREPTOCOCCUS	
COCCUS	STAPHYLOCOCCUS	

4. Each student will then be given a set of unlabelled slides. Using their observations from Steps 2 and 3 of this activity, the students will determine to which subgroup each unlabelled specimen belongs.

Post-Lab Questions (assigned as homework):
For each of the subgroups of bacteria you have just identified, name one human disease that is caused by that type of bacteria, describe how it is transmitted and list some of the symptoms of that disease.

DAY 2 -- INTRO: (30 minutes):
Word Search, see link below, that leads into the lecture of the day. They can work in groups if they are having trouble, one could find the word while the other comes up with a definition they think works.

For link to the word search created by Discovery.com:

http://school.discovery.com/curriculumcenter/bacteria/wordplay.html

Lecture: (15 minutes)

See attached outline.

Lab: (45 minutes) NOTE- this lab will take 2 days!!

Bacterial Colony Growth

Objective: The students will learn about aseptic technique and the growth of colonies by culturing different bacteria that they are exposed to every day.

Materials: sterilized Petri dishes containing nutrient agar, incubator, sterile cotton swabs

Procedure:

1. Obtain one of the sterile Petri dishes from your instructor.

2. Inoculate the medium by doing one of the following:
   a) Use a sterile cotton swab to transfer some grime from the drain in the sink to the medium
   b) Let a living insect walk across the medium
   c) Expose the medium to air in the room for 5 minutes. Different groups of students should try the air in different rooms.
   d) Drag a coin over the medium.
   e) Touch the medium with the tips of your fingers. Be sure to wash your hands thoroughly afterwards.
   f) Use a sterile cotton swab to transfer some dust from a window ledge to the medium.

3. Immediately after inoculation, place the lid on the Petri dish and seal it with transparent tape. DO NOT RE-OPEN THE PETRI DISH! Label each Petri dish with the source of the inoculation and your name.

4. Return the inoculated media to your instructor who will then place the Petri dishes upside down in the incubator. The media will then be incubated at 25° C to 35° C for 24-48 hours. Place the cotton swabs in the proper disposal container.

5. Following the incubation period, observe you inoculated media, but DO NOT OPEN THE PETRI DISHES. There is the possibility that some infectious pathogens may have grown in the nutrient area.

Observations: Note any bacteria that have grown and classify them. (This is to be done on Day 3 and turned in on Day 4 with Post lab question.)

Post Lab Question: Assigning for homework and is due the beginning of class Day 4

Suppose your instructor forgot about the Petri dishes in the incubator and left them in there at 350° C for 2 weeks. Would the colonies continue to grow for the entire two weeks, or would something happen to prevent this type of growth. Explain and give reasons for your answer.

DAY 3:

Lab: (30 minutes) Continued from Day 2

Class Activity: (45 minutes) Quiz, see link below, done aloud as a class. Teacher reads the question while the students work in teams to answer the questions. The teams are challenged by time as well as by who gets it right. You could create a points system and reward system as well.

For link to the quiz created by Discovery.com:

http://school.discovery.com/curriculumcenter/bacteria/quiz.html

Lecture: (15 minutes)

See attached outline.

DAY 4:

Lab: (90 minutes) Post lab question from day 3 due at beginning of class.

Investigating the Effects of Light, Temperature and pH on Bacterial Growth

Objective: The students will expose bacteria to change various environmental factors such as temperature, light and growth.

Materials: sterile cotton swabs, pond water (bacterial source), 13 Petri dishes containing sterile nutrient agar (6 of these Petri dishes will contain agar that has been treated with solutions of differing pH [pH = 2, 4, 7, 8, 10, and 12]), incubator, dark closet, incandescent light source, fluorescent light source

Procedure A: Effect of Temperature on Bacterial Growth

1. Using a sterile cotton swab for each dish, inoculate four of the Petri dishes with the pond water provided.

2. Seal each dish with transparent tape and label them with the following temperatures: 4° C, 23° C, 35° C and 60° C. Also label the dishes with your name.

3. Return the sealed dishes to your instructor who will place each dish in its respective incubator (a refrigerator will be used for 4° C).

Procedure B: Effect of Light on Bacterial Growth

1. Using a sterile cotton swab for each dish, inoculate four of the Petri dishes with the pond water.

2. Seal each dish with transparent tape and label them with the following: dark, incandescent light, fluorescent light (and your name!).

3. Return the dishes to your instructor who will place each dish under its respective light source. These dishes will be kept at room temperature.

Procedure C: Effect of pH on Bacterial Growth

1. Using a sterile cotton swab for each dish, inoculate the 6 pre-labeled Petri dishes (each contains a solution at a different pH).

2. Seal each dish with transparent tape and return them to your instructor. These plates will be incubated at room temperature. Don't forget to put your name on the dishes

3. Place all cotton swabs in the proper disposal container.

Observations: NOTE- this is to be done on Day 5 and turned with the Post Questions for Day 6!

1. Retrieve your 13 Petri dishes from the instructor.

2. Record your observations in the form of a chart. Be sure to look at the shape, size, structure, texture and color of any colonies that have formed. If no colonies formed, be sure to note that in your chart.

3. Once you have finished making your observations, return the Petri dishes to your instructor who will disinfect and dispose of them.

Post-Lab Questions:

1. At which temperature did the bacteria grow best? At which temperature was the least amount of growth observed? Why?

2. Under which light source did the bacteria grow best? Under which light source was the least amount of growth observed? Why?

3. At which pH did the bacterial grow best? At which pH was the least amount of growth observed? Why?

4. Using your observations, explain why many bacteria grow well in the human body.

5. What other factors could affect the growth of bacteria. For each of the factors you name, as well as the factor investigated in this activity, find examples of bacteria that will grow at the two extremes of these factors (i.e. low temperature and high temperature).

DAY 5:

Lab: (75 min. total- ~40 min. for each lab) Continued from Day 4 and new lab

Effects of Antiseptics and Disinfectants in Bacterial Growth

Objective: The students will investigate the effectiveness of various disinfectants and antiseptics on the growth of bacteria.

Materials: sterile Petri dishes containing nutrient agar, sterile cotton swabs, pond water (source of bacteria), small paper discs (sterile), tweezers, Bunsen burner (to sterilize tweezers after each inoculation), commercial disinfectant, carbolic acid, commercial antiseptic, ethanol (ethyl alcohol), antibacterial soap

Procedure:

1. Obtain one Petri dish from your instructor.
2. Use a sterile cotton swab to inoculate the entire medium in the Petri dish with the pond water.
3. Take 5 paper discs. Using the tweezers, dip the first disc in the commercial disinfectant and place the disc near the outside edge of the medium.
4. Wash the tweezers with water. Dry the excess water from the tweezers and sterilize them, by holding them in the Bunsen burner at a 45o angle for about 3 seconds.
5. Repeat steps 3 and 4 for each of the remaining solutions
6. Once all of the discs have been place on the medium, seal the dish with transparent tape. Label the dish with the names of each of the solutions, on top of their respective discs. Be sure to put your name on the dish as well.
7. Return your Petri dish to your instructor who will incubate the dish at 25-35o C for 24-48 hours. Also, place the cotton swabs in the proper disposal container.

Observations: (NOTE: This lab is to be done on a Friday so the bacteria can grow over the week and the observations can be done the following Monday.)

1. Retrieve your Petri dish from the instructor.
2. Using a ruler, measure the diameter of the area of growth inhibition for each of the solutions. Record these figures carefully in your notes.
3. Construct a bar graph showing the amount of growth inhibition provided by each solution.

Post-Lab Questions: (Due Day 7 with the Observations)

1. Which substances were most effective in inhibiting bacterial growth.

2. Which of these substances cannot be used to clean human tissue? Why not?

3. The local hospital has been infected with a highly infectious form of Staphylococcus bacteria. The pathogen is spread through infected instruments and by direct contact. How would you use antiseptics and disinfectants to stop the spread of the pathogen to uninfected parts of the hospital?

Lecture: (15 minutes)

See attached outline.

DAY 6:

Lab: (30 minutes) Continued from Day 5.

Intro: (45minutes) ---WARNING: WILL BE VERY MESSY!!!

Materials: five Styrofoam plates, five different colors of washable paint, two pieces of white card stock paper that is legal sized for each student

Objective: To see how germs can be spread from one person to another as well as how well we wash our hands.

Procedure:

1. Break into groups of four or five and so to your assigned station that has the prepared paint and paper ready.

2. Write your names on the top of the each paper and then write 1st, 2nd, 3rd, 4th, and 5th on the papers so you can identify each hand print you will make on the paper. One list should be labeled before washing and the other after washing.

3. Choose a different color from everyone else in your group and stick your non-dominate hand down into it. Do not squish it between your fingers or have it dripping off.

4. Now touch your hand to the paper above or near where you wrote 1st.

5. Now touch your painted hand to someone else's painted hand and then touch the hand to the paper near the 2nd mark.

6. Continue the process until you have touched every group members' hand.

7. If you run out of your color then dip your hand again but make sure that you do not transfer any other color paint to the plate.

8. Go to the assigned sink and begin washing your hands fro 10 seconds, then press your hand to the paper under the 1st mark.

9. Continue washing in increments of 10 seconds and then touch your hand to the 2nd, 3rd, or 4th mark.

10. If your hands are still dirty then wash them with soap but do not take a reading.

11. Once your hands are clean, clean up the area to make sure there are no stray paint marks.

12. Let the paint dry over night and hand in the next day with your written observations (i.e. after touching the 2nd person I had only a little of my paint left but a lot of the 1st person and only a little of the 2nd persons).

Lecture: (15 minutes)

See attached outline.

DAY 7 -- Observations from Day 5 LAB, Post lab questions, Observation and paint "graph" from Day 6 are all due at the beginning of class. A lab report detailing all four lab activities, all observations and all conclusions is due one week from today.

EVALUATION

Each student will turn in a Lab Report one week after the lab exercises are completed and it will be graded by a standard rubric given out at the beginning of the year/semester. They will also have to turn in a copy of all their observations, graphs, and Pre/Post lab questions for a grade, usually that are worth ten points each. At the end of each unit there will be a test, not included, covering the lecture and the lab activities. The students will also be graded on the introduction activities to the lectures.

NOTE: All lab activities and pre/post lab questions came from the website:

http://educ.queensu.ca/~science/main/concept/biol/b08/B08LACG2.htm

LECTURE OUTLINE

Bacteria

General Biology
Properties of Bacteria
-prokaryotic (no membrane-enclosed nucleus)
-microscopic organisms, single-celled creatures which live mostly on the surfaces of objects where they grow as colonies
-no mitochondria or chloroplasts
-a single chromosome
-a closed circle of double-stranded DNA
-with no associated histones
-ribosomes differ in their structure from those of eukaryotes
-have a rigid cell wall made of peptidoglycan.
-The plasma membrane is a phospholipid bilayer but contains no cholesterol or other steroids.
-form a single spore when their food supply runs low. Water is removed from the spore and metabolism ceases, and they can survive for up to 50 years with out desiccation.
-long, whip-like structures called flagella, which are rotated like tiny outboard motors to propel themselves through liquid environments. They may also reverse the direction in which their flagella rotate so that they tumble about in one place.
-Other bacteria secrete a slime layer and ooze over surfaces like slugs. Others are fairly stationary.

Shape

-Cocci (singular coccus)- The simplest shape, round sphere or ball.
-Cylindrical- called rods (singular rod).
-Spirilla (singular spirillum)- basically rods but instead of being straight they are twisted or bent or curved, sometimes in a spiral

Reproduction and Growth

-mostly asexual reproduction (binary fission) which results in cell division.
-Two identical clone daughter cells are produced.
-Some bacteria form more complex reproductive structures that facilitate the dispersal of the newly-formed daughter cells.
-Examples include fruiting body formation by Myxococcus and arial hyphae formation by Streptomyces.
-no mitosis
-any sexual reproduction very different from that of eukaryotes; no meiosis
-Growth in liquid media, with stirring, most often occurs as an even cell uspension making the cultures easier to divide and transfer compared to solid media, although the isolation of individual cells from liquid media is extremely difficult.
-Solid growth media such as agar plates are used to isolate pure cultures of a bacterial strain. When quantitation of growth or large volumes of cells are required liquid growth media are generally used.

-The first phase of growth is the lag phase. It is a period of slow growth which is most often attributed the need for cells to adapt to fast growth. It has high biosynthesis rates; enzymes needed to metabolise a variety of substrates are produced.
-The second phase of growth is the logarithmic phase (log phase or exponential phase). It is marked by rapid exponential growth.
-growth rate (k) is the rate at which cells grow
-generation time (g) is the time it takes the cells to double
-nutrients are metabolized at maximum speed until they are all gone.
-The final phase of growth is the stationary phase. It is caused by depleted nutrients. The cells begin to shut down their metabolic activity, as well as break-down their own none-essential proteins. It is the transition from rapid growth to dormancy.

What they eat
-Bacterial metabolism can be divided broadly on the basis of electron donors and electron acceptors and by the source of carbon used. Most bacteria are heterotrophic; using organic carbon compounds as both carbon and energy sources.
-Some bacteria absorb food from the material they live on or in. Some of these bacteria can live off unusual "foods" such as iron or sulfur. The microbes that live in your gut absorb nutrients from the digested food you've eaten.
-In aerobic organisms, oxygen is used as the terminal electron acceptor.
-In anaerobic organisms other inorganic compounds, such as nitrate, sulfate or carbon dioxide as terminal electron acceptors leading to the environmentally important processes of denitrification, sulfate reduction and acetogenesis, respectively.
-Non-respiratory anaerobes use fermentation to generate energy and reducing power, secreting metabolic by-products (such as ethanol in brewing) as waste.
-Facultative anaerobes can switch between fermentation and different terminal electron acceptors depending on the environmental conditions in which they find themselves.
-Example: Clostridium thermocellum

Origin and History
-It may seem surprising that bacteria can leave fossils at all. However, one particular group of bacteria, the cyanobacteria or "blue-green algae," have left a fossil record that extends far back into the Precambrian - the oldest cyanobacteria-like fossils known are nearly 3.5 billion years old, among the oldest fossils currently known.
-Bacteria have also been found in amber and in mummified tissues. It is also sometimes possible to infer the presence of disease-causing bacteria from fossil bones that show signs of having been infected when the animal was alive.
-The first bacteria were observed by Anton van Leeuwenhoek in 1674 using a single-lens microscope of his own design.
-The name bacterium was introduced much later, by Ehrenberg in 1828, derived from the Greek word _____ meaning "small stick".

The Theory of Endosymbiosis
-concerns the origins of mitochondria and chloroplasts.
-originated as separate prokaryotic organisms which were taken inside the cell as endosymbionts.

-Mitochondria developed from proteobacteria and chloroplasts from cyanobacteria.
-eukaryotic cells originated as communities of interacting entities, including endosymbiotic spirochaetes that developed into eukaryotic flagella and cilia.
-peroxisomes may have an endosymbiotic origin has also been considered, although they lack DNA. They may have been the first endosymbionts, allowing cells to withstand growing amounts of free molecular oxygen in the Earth's atmosphere

Evidence of this event
-Both mitochondria and plastids contain DNA, which is fairly different from that of the cell nucleus, and that is similar to that of bacteria (in being circular and in its size).
-New mitochondria and plastids are formed only through a process similar to binary fission.
-They are surrounded by two or more membranes, and the innermost of these shows differences in composition compared to the other membranes in the cell. The composition is like that of a prokaryotic cell membrane.
-Much of the internal structure and biochemistry of plastids, for instance the presence of thylakoids and particular chlorophylls, is very similar to that of cyanobacteria.
-DNA sequence analysis and phylogenetic estimates suggests that nuclear DNA contains genes that probably came from the plastid.
-Some proteins encoded in the nucleus are transported to the organelle.
-Both mitochondria and plastids have small genomes compared to bacteria. Most genes needed for mitochondrial and plastid function are located in the nucleus.
-Many originate from the bacterial endosymbiont.
-These organelle's ribosomes are like those found in bacteria.

How they are helpful
-Many animals are completely dependent on bacteria to digest their food for them, particularly herbivores, large vertebrates like cows and sheep, to small invertebrates like termites and collembola all are dependant on there comensal bacteria to stay alive.
-They produce the best antibiotics and with the help of modern microbiological techniques they can now be used to produce many medically import products and even biodegradable planet friendly plastics.
-Organic carbon, in the form of dead and rotting organisms, would quicklydeplete the carbon dioxide in the atmosphere if not for the activity of decomposers. This may not sound too bad to you, but realize that without carbon dioxide, there would be no photosynthesis in plants, and no food
-The cycling of nitrogen is another important activity of bacteria.
-Plants rely on nitrogen from the soil for their health and growth, and cannot acquire it from the gaseous nitrogen in the atmosphere. The primary way in which nitrogen becomes available to them is through nitrogen fixation by bacteria.
-Other denitrifying bacteria metabolize in the reverse direction, turning nitrates into nitrogen gas or nitrous oxide. When colonies of these bacteria occur on croplands, they may deplete the soil nutrients, and make it difficult for crops to grow.
-Highly specialized groups of microorganisms play important roles in the mineralization of specific classes of organic compounds.
-For example, the decomposition of cellulose, which is one of the most abundant constituents of

plant tissues, is mainly brought about by aerobic bacteria that belong to the genus Cytophaga. This ability has also been utilized by humans in industry, waste processing, and bioremediation.
-Many other bacteria are found as symbionts in humans and other organisms. For example, the presence of the gut flora in the large intestine can help prevent the growth of potentially harmful microbes.
-Bacteria capable of digesting the hydrocarbons in petroleum are often used to clean up oil spills. Some beaches in Prince William Sound were fertilized in an attempt to facilitate the growth of such bacteria after the infamous 1989 Exxon Valdez oil spill. These efforts were effective on beaches that were not too thickly covered in oil.
-Bacteria, often in combination with yeasts and molds, are used in the preparation of fermented foods such as cheese, pickles, soy sauce, sauerkraut, vinegar, wine, and yogurt.

Bacteria make antibiotics???
-Commercially, antibiotics are the most important of these substances (called secondary metabolites). An antibiotic is a substance that suppresses the growth of micro-organisms such as bacteria and fungi, and they are produced by some bacteria to prevent other bacteria from growing near them and using up their food.

-Antibiotic	Bacterial Species
-Tetracycline	Streptomyces remosus
-Streptomycin	Streptomyces riseus
-Cyclohexamide	Streptomyces griseus
-Neomycin	Streptomyces frodiae
-Cycloserine	Streptomyces orchidaceus
-Erythromycin	Streptomyces erythreus
-Kanamycin	Streptomyces kanamyceticus
-Lincomycin	Streptomyces lincolnensis
-Nystatin	Streptomyces noursei
-Polymyxin B	Bacillus polymyxa
-Bacitracin	Bacillus licheniformis

Bacteria make vitamins
-Vitamin B12 is essential for normal living in all animals and a deficiency of it causes a disease called pernicious anemia. Commercially, vitamin B12 is produced by several bacteria, the most important of which is Pseudomonas denitrificans. Other important producers are species of the genus Propionibacterium.
-The other important vitamin made commercially by micro-organisms is Riboflavin. Most riboflavin is produced by a fungus called Ashbya gossifyii, however, bacteria are used to produce some as well.

Bacteria make Amino acids
-Bacterially Produced Amino-acids Used as Food Additives
-Lysine- Nutritive additive in bread
-Glutamate- Flavor enhancer, meat tenderizer
-Glycine- Flavor enhancer in sweet foods

-Cysteine- Antioxidant in bread and fruit juices
-Tryptophan and Histidine- Antioxidant
-Methionine -Nutritive additive in soy products
-Phenylalanine and Aspartic acid-Sweetener in soft drinks

How they can be harmful

-The role of bacteria in disease and infection is important. Some bacteria act as pathogens and cause:

-Clostridium tetani	tetanus
-Corynebacterium diphtheria	diphtheria
-E. coli	acute kidney inflammation
-Hemophilus influenzae	meningitis
-Lactobacillus acidophilus	cavities
-Mycobacterium tuberculosis	tuberculosis
-Neisseria gonorrhoeae	gonorrhoea
-Neisseria meningitides	spinal menigitis
-Salmonella typhimurium	food poisoning
-Shigella dysenteriae	dysentery
-Streptococcus mutans	cavities
-Streptococcus pneumoniae	pneumonia
-Yersinia pestis	plague

-Some bacterial infections can spread throughout the host's body and become systemic.
-In plants, bacteria cause leaf spot, fireblight, and wilts. The mode of infection includes contact, air, food, water, and insect-borne microorganisms.

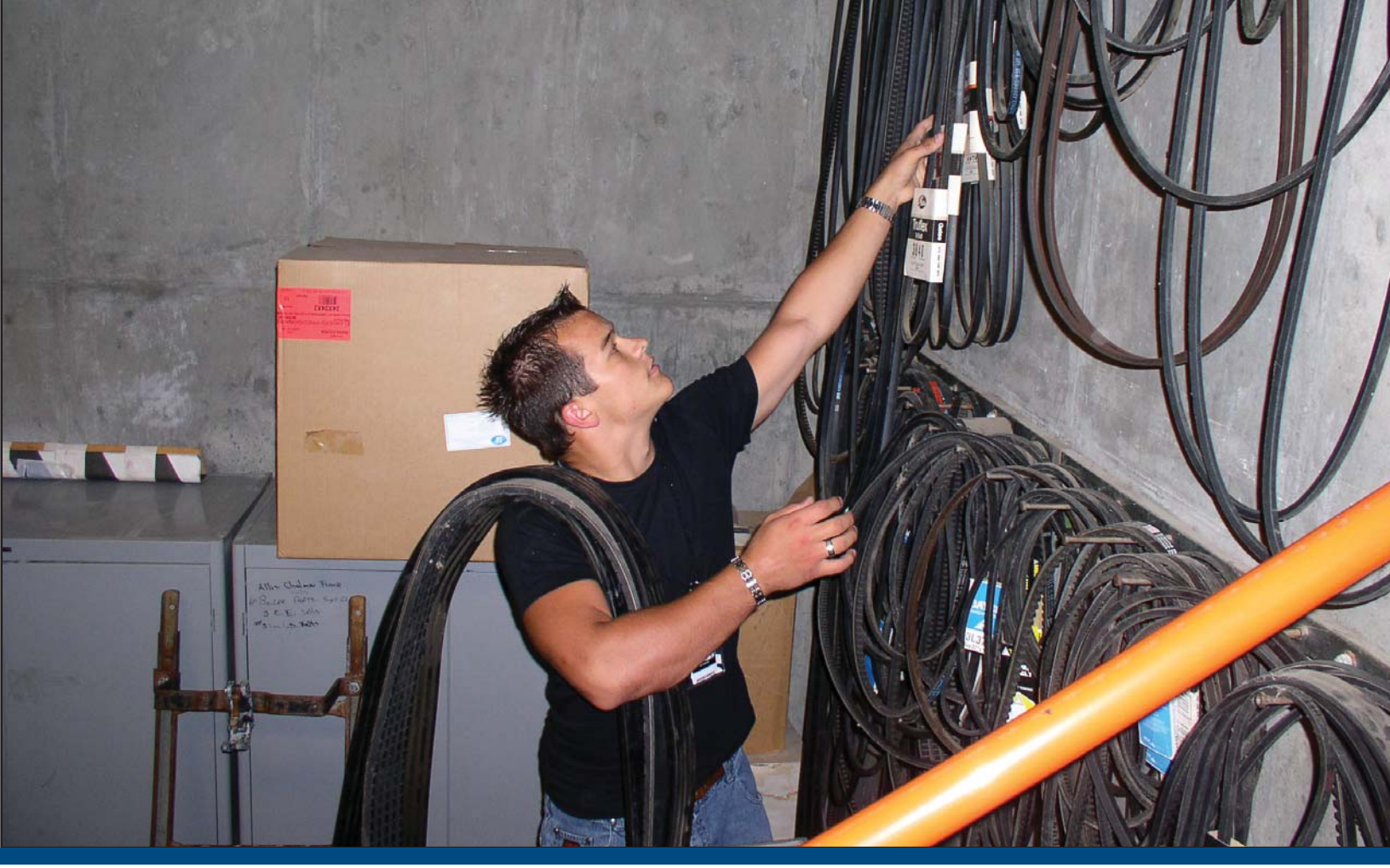
How we can fight them off

-The hosts infected with the pathogens may be treated with antibiotics, which can be classified as bacteriocidal and bacteriostatic, which at concentrations that can be reached in bodily fluids either kill bacteria or hamper their growth, respectively.
-Antiseptic measures may be taken to prevent infection by bacteria, for example, by swabbing skin with alcohol prior to piercing the skin with the needle of a syringe.
-Sterilization of surgical and dental instruments is done to make them sterile or pathogen-free to prevent contamination and infection by bacteria.
-Sanitizers and disinfectants are used to kill bacteria or other pathogens to prevent contamination and risk of infection.

Strange Facts about Bacteria

-The record for underground living goes to a species of Chemolithotrophic bacteria found in Basalt deposits 1500m (4700ft) underground in solid rock. This really is solid rock, scientists only learned about these bacteria when drilling for oil. Checking drill cores brought up from these depths for signs of oil the found living bacteria.
-The air is full of bacteria. This is not surprising, when you realize that they are so small you cannot see them with your naked eye it is not hard to accept that they should get blown around easily. However it is not just surface bacteria getting caught up in the breeze. Recent discoveries have shown that some bacteria spend their whole lives in the atmosphere, growing and

reproducing in the clouds above our heads.
-Scientist know of bacterial species that live all their lives in the ice of glaciers and other bacteria have often found in the snows of the North and South poles. Until recently scientists had thought bacteria found in these latitudes were just blown there by the winds but in 2000AD they proved that some of these species are different to any others and live at the North pole all year round where the temperature varies between -17 and -85 degrees C.
-Some species are happy at 75° C while others think even this is cool. Species of Aquifex can live in water as hot as 95° C, this is just 5 degrees away from the boiling temperature of water. This is not the world record though, that belongs to a species of Archaea which is happy to grow in water around deep sea hydrothermal vents at temperatures as high as 106° C (at these great depths, several miles down, the pressure stops the water from boiling and keeps it liquid).



Section H: How to Contact Us?

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