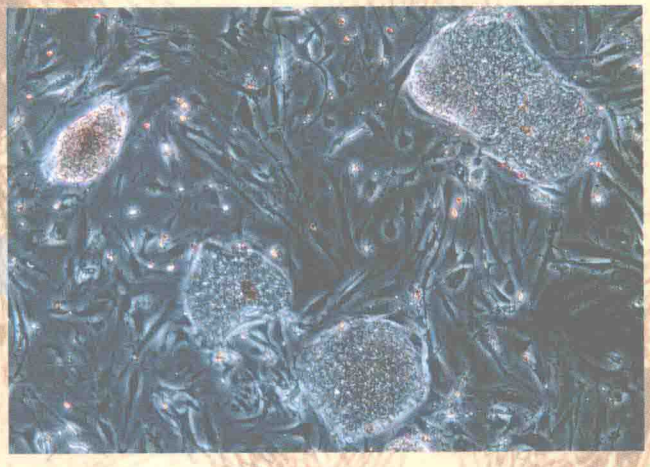
Stem Cells



and the Future of Regenerative Medicine

NATIONAL RESEARCH COUNCIL • INSTITUTE OF MEDICINE

Stem CELLS and the FUTURE OF REGENERATIVE MEDICINE

Committee on the Biological and Biomedical Applications of
Stem Cell Research

Board on Life Sciences
National Research Council

Board on Neuroscience and Behavioral Health
Institute of Medicine

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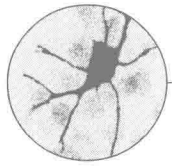

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Second, this report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

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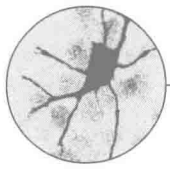
Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by Ronald Estabrook of the University of Texas Southwestern Medical Center and Floyd Bloom of the Scripps Research Institute. Appointed by the

National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.



Preface

Stem cell research has the potential to affect the lives of millions of people in the United States and around the world. This research is now regularly front-page news because of the controversy surrounding the derivation of stem cells from human embryos. Realizing the promise of stem cells for yielding new medical therapies will require us to grapple with more than just scientific uncertainties. The stem cell debate has led scientists and nonscientists alike to contemplate profound issues, such as who we are and what makes us human beings.

The excitement and controversy surrounding stem cells caused the National Research Council's Board on Life Sciences and the Institute of Medicine's Board on Neuroscience and Behavioral Health to recommend that the National Academies sponsor a workshop to assess the scientific and therapeutic value of stem cells. The presidents of the National Academies agreed and provided most of the funding that supported the production of this report. The Ellison Foundation provided additional funding.

In a collaboration of the two boards, the Committee on the Biological and Biomedical Applications of Stem Cell Research was formed. The persons appointed to serve on the committee have a wealth of expertise in the basic and clinical biomedical sciences but do not themselves perform stem cell

research. The latter characteristic was intended to ensure that none of the committee members had a vested interest in any form of stem cell research. Expertise represented on the committee includes molecular biology, immunology, cell biology, cardiology, hematology, neurosciences, developmental biology, infectious disease, cancer, and bioethics, all of which are integrally related to stem cell research and its potential for developing tissue-replacement therapies that will restore lost function in damaged organs.

At the committee's workshop, held on June 22, 2001, scientists, philosophers, ethicists, and legal experts presented their views in two general categories. First, leading scientific investigators addressed the following scientific questions: What are stem cells? What are their sources, and what biological differences exist among cells of different origins? How do these differences translate into advantages or disadvantages for research and medical applications? What is the potential of stem cells for regenerative medicine, and what obstacles must be overcome to make them useful for new medical therapies? Second, experts in philosophy, law, and ethics presented a variety of ethical and other arguments relevant to public-policy considerations on stem cells. Audio files of the speakers' presentations are available until December 31, 2002, at the workshop Web site: www.nationalacademies.org/stemcells.

This report presents the committee's findings and recommendations. It is based on careful consideration of information presented at the workshop and on data and opinions found in the scientific and other scholarly literature. The committee is extremely respectful of all perspectives in this debate and has taken them into account in forming its recommendations.

I wish to thank all the members of the committee for their valuable contributions and especially for their insights into both the scientific and the societal issues. In particular, Corey Goodman, chair of the Board on Life Sciences, was responsible for much of the initial impetus for the workshop. I also wish to acknowledge the staff of the National Research Council (Robin Schoen, Bridget Avila, and Fran Sharples) and the

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Bert Vogelstein, Chair
Committee on the Biological and Biomedical
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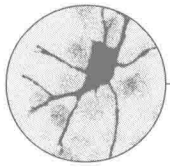

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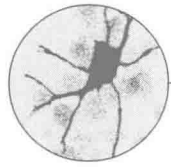

Executive Summary

Stem cell research offers unprecedented opportunities for developing new medical therapies for debilitating diseases and a new way to explore fundamental questions of biology. Stem cells are unspecialized cells that can self-renew indefinitely and also differentiate into more mature cells with specialized functions. Research on human embryonic stem cells, however, is controversial, given the diverse views held in our society about the moral and legal status of the early embryo. The controversy has encouraged provocative and conflicting claims both inside and outside the scientific community about the biology and biomedical potential of both adult and embryonic stem cells.

The National Research Council and Institute of Medicine formed the Committee on the Biological and Biomedical Applications of Stem Cell Research to address the potential of stem cell research. The committee organized a workshop that was held on June 22, 2001. At the workshop, the committee heard from many leading scientists who are engaged in stem cell research and from philosophers, ethicists, and legal scholars. (Audio files of the speakers' presentations are available until December 31, 2002, at the workshop Web site, www.nationalacademies.org/stemcells.)

The participants discussed the science of stem cells and a variety of ethical and other arguments relevant to public policy as it applies to stem cells. The committee considered the

information presented, explored the literature on its own, and contemplated the substance and importance of the preliminary data from recent stem cell experiments. The committee's deliberations on the issues led to the following conclusions and recommendations.

- Experiments in mice and other animals are necessary, but not sufficient, for realizing the potential of stem cells to develop tissue-replacement therapies that will restore lost function in damaged organs. Because of the substantial biological differences between nonhuman animal and human development and between animal and human stem cells, studies with *human* stem cells are essential to make progress in the development of treatments for *human* disease, and this research should continue.
- There are important biological differences between adult and embryonic stem cells and among adult stem cells found in different types of tissue. The implications of these biological differences for therapeutic uses are not yet clear, and additional data are needed on all stem cell types. Adult stem cells from bone marrow have so far provided most of the examples of successful therapies for replacement of diseased or destroyed cells. Despite the enthusiasm generated by recent reports, the potential of adult stem cells to differentiate fully into other cell types (such as brain, nerve, pancreas cells) is still poorly understood and remains to be clarified. In contrast, studies of human embryonic stem cells have shown that they can develop into multiple tissue types and exhibit long-term self-renewal in culture, features that have not yet been demonstrated with many human adult stem cells. The application of stem cell research to therapies for human disease will require much more knowledge about the biological properties of all types of stem cells. Although stem cell research is on the cutting edge of biological science today, it is still in its infancy. Studies of both embryonic and adult human stem cells will be required to most efficiently advance the scientific and therapeutic potential of regenerative medicine. Moreover, research on embryonic stem cells will be important to inform research on