C I R M

CALIFORNIA INSTITUTE FOR REGENERATIVE MEDICINE ANNUAL REPORT 2009

SENATOR BARBARA BOXER

"In just 5 years the Institute is already helping making California a worldwide leader in stem cell research and breakthrough treatments that will save lives. I was proud to be an early supporter of Proposition 71, which offered the promise of new treatments for diseases such as cancer, Parkinson's and Alzheimer's... and gave scientists the support that they need and deserve to produce the medical breakthroughs of tomorrow."

TURNING STEM CELLS INTO CURES

Autoimmune Diseases
Arthritis
Crohn's Disease
Devic's Syndrome
Multiple Sclerosis
Osteoporosis
Systemic Lupus Erythematosus (Lupus)
Systemic Sclerosis
Type 1 Diabetes

Cancers
Bladder
Brain/Central Nervous System
Breast
Colon/Lower Bowel
Endometrium/Cervix/Ovary
Esophagus
Kidney
Leukemia
Liver
Lungs/Respiratory System
Lymphoma
Myeloma
Oral Cavity
Pancreas
Prostate
Skin
Stomach

Cardiovascular Diseases
Acute Ischemic Heart Disease (angina)
Myocardial Infarction (heart attack)
Chronic Ischemic Heart Disease (athersclerotic heart disease)
Cardiomyopathy
Cerebrovascular Disease (stroke)

Circulatory/Respiratory Diseases
Chronic Obstructive Pulmonary Disease
Pulmonary Fibrosis

Injuries
Severe Burns
Spinal Cord Injury

Eye Disorders
Macular Degeneration
Retinitis Pigmentosa

Infectious Diseases
HIV/AIDS

Metabolic Diseases
Adrenoleukodystrophy
Aspartylglycosaminuria
Canavan's Disease
Cystic Fibrosis
Fabry Disease
Fucosidosis
Gaucher Disease
Leukodystrophy
Mucopolysaccharidoses
Niemann-Pick Disease
Pompe Disease
Porphyria
Sickle Cell Disease
Tay-Sachs Disease
Type 2 Diabetes

Muscular Dystrophies
Becker
Duchenne
Emery Dreifuss
Facioscapulohumeral
Fukuyama
Limb Girdle
Myasthenia Gravis
Myotonic Dystrophy

Neurological Diseases of Adulthood
Alzheimer's Disease
Huntington's Disease
Lou Gehrig's Disease (ALS)
Parkinson's Disease

Neurological Diseases of Childhood
Asperger Syndrome
Autism
Cerebral Palsy
Childhood Disintegrative Disorder
Down Syndrome
Epilepsy
Hydrocephalus
Rett Syndrome

the mission of CIRM

To support and advance stem cell research and regenerative medicine

under the highest ethical and medical standards for the discovery and development of cures, therapies, diagnostics and research technologies to relieve human suffering from chronic disease and injury.

Sharon Hayes has macular degeneration. "If something new came out, I would try it in a heartbeat."

The California Institute for Regenerative Medicine (CIRM)

was established by Proposition 71,

the California Stem Cell Research and Cures Initiative.

The statewide ballot measure,
which provided $3 billion in funding for stem cell research
at California universities and research institutions,
was approved by 59% of California voters on November 2, 2004,
and called for the establishment of a new state agency to make grants
and provide loans for stem cell research, research facilities
and other vital research opportunities.
The Independent Citizens Oversight Committee (ICOC)
is the 29-member Governing Board of the Institute;
the Governing Board members represent expertise from California's leading public
and private universities, non-profit hospitals and research institutions,
patient advocacy groups and biotechnology.

Cover photo:
Smooth muscle cells
derived from
human embryonic
stem cells.

Today's Investment • Tomorrow's Therapy • Future Cures

ROBERT N. KLEIN

Proposition 71 at Five Years: The Stem Cell Revolution is launched.

The tragedy of George Bush's restriction of federal funding for most embryonic stem cell research created a gift for California.

While United States stem cell research was hobbled by ideological restrictions, California's voters passed Proposition 71, funding a substitute for a national program across the entire range of stem cell research and propelling California into national and international leadership. A recent study funded by The National Science Foundation (NSF) stated, "California has established itself as a major center for stem cell research. Recruitment of world-class stem cell scientists from across the globe has been a direct result of CIRM funding."(1) The study summarizes Proposition 71's impact by stating: "In its short history, the CIRM has taken on a vigorous life of its own. It is apparent that the shift of a major focus for stem cell research to California will have a significant effect into the future on the geographic distribution of biological science and biotechnology infrastructure in the United States; on the location of university, biotechnology, and pharmaceutical research and start-up firms; and on the investment of venture capital. Evidence for this is the $300 million the CIRM has invested in stem cell facilities, already leveraged to more than $1 billion in linked donations."(1)

California's Scientific Renaissance. Proposition 71, by its 5th Anniversary has launched "California's Scientific Renaissance" through The Stem Cell Revolution. On this anniversary it is, therefore, important to ask: what does Proposition 71 uniquely deliver to California? What drives this revolution; and, does the change in the United States' Presidential leadership eliminate the need for California's unique scientific, funding and governance model?

What Drives the Proposition 71 Stem Cell Revolution? In the aggregate, 10 key elements of Proposition 71 provide California's basic and clinical stem cell scientists an unmatched strategic advantage in the national and international race to reduce human suffering through this new medical therapy field.

One, An Annual Funding Floor with Critical Scale. An annual funding floor with critical scale provides California's research institutions and the California-based biotech industry a long enough period of assured funding to launch new research institutes, departments, and biotech companies. Private capital and public institutional capital markets (including academic, university and non-profit institutions) abhor economic uncertainty. Proposition 71 provides a sufficient long-term assurance of funding and scale to recruit and competitively force the commitment of substantial capital assets (by public and private medical institutions), concurrent with Proposition 71 funding, as the price of meaningful participation in the stem cell revolution.

Two, A Constitutional Guarantee to Protect the Pursuit of "Pluripotent and Progenitor Stem Cell Research." A constitutional guarantee to protect the pursuit of "Pluripotent and Progenitor Stem Cell Research" provides the security that major ideological changes in the leadership of state legislative and executive

administrations will not result in the destruction of careers committed to the scientific vision of converting stem cell discoveries into effective medical therapies. The type of ideological repression of science represented by the attempts of the United States House of Representatives in 2002 and 2003 to criminalize embryonic stem cell research and Michigan's criminal statutes from 1998 to 2008, do not and will not represent a threat that could impact the lives and careers of California's dedicated scientists and clinicians. Even today, with President Obama's Executive Order to empower the National Institutes of Health's funding of embryonic stem cell research, no new embryonic stem cell lines can be derived with National Institutes of Health (NIH) funds; but, California can fund these new line derivations, including critically important disease-specific cell lines.

Three, Empowering the Passion to Reduce Human Suffering. Empowering the passion to reduce human suffering is a jewel of Proposition 71's mission. The most precious asset of any state or nation is the dedicated, passionate commitment of its citizens to improve the future lives of its people. Proposition 71 funds the brilliant new ideas of California's young scientists and clinicians. The SEED Grants, the New Faculty grants, and the Scientific and Clinical Internship grants, have given California stem cell scientists their start making it possible for them to dedicate the most critical first decade of their professional careers and their families' lives to stem cell therapy research and development. Their efforts will reduce the future human suffering for their families, their state and the world's children. Proposition 71 will continue to be of critical value not only to California, but to all stem cell research.

Four, Building and Sustaining International Momentum for California's Scientists and Clinicians. Proposition 71 can strategically build and sustain the international scientific momentum for California's scientists and clinicians to capture global leadership in the stem cell field. Seven nations, recognizing this leadership—Canada, the United Kingdom, Spain, Germany, Australia's state of Victoria, Japan, and China—have entered bilateral funding agreements with CIRM, the scientific funding agency created by Proposition 71. California gains scientific and clinical leverage from this collaborative funding—matching California's best scientists with many of the best from around the world. These collaborations present the promise of saving California's chronically ill and injured years of suffering and enhance the potential for early therapy successes by bringing the knowledge of the best stem cell scientists of the world together with California's leaders to safely accelerate the development of novel therapies. Chronic disease knows no national boundaries and medical science will not meet the moral mandate for speed and safety in this complex scientific revolution, without air-bridges that move knowledge seamlessly over international borders.

Five, Building Teams and Dissolving Barriers. Proposition 71 dissolves the walls blocking scientific collaboration between research institutions and between departments in those institutions. Proposition 71 incentivizes collaborative science (team building) requiring the best scientists of every institution to partner with the best "competitor" institutions if their team is to prevail in the world class "peer review" of their scientific applications. Academic and non-profit biomedical research outside of California reportedly too often fits the descriptive criticism of Ohio State University President E. Gordon Gee, who commented, "The many elements

5 YEARS, 260 WEEKS, 1,100 HOURS OF PUBLIC MEETINGS OF PROPOSITION 71'S GOVERNING BOARD;

State Supreme Court and federal court victories validate the initiative and the vision of 7 million voters;

$1.0 billion of medical research and facilities authorized;

$1.2 billion in donor and institutional matching funds; no other state agency in the history of California approaches this record;

12 world class research institutes and centers of excellence funded;

Scientists from 7 nations join California's stem cell teams;

FDA approved clinical trials in process...
Lives saved;

Over 400 new research discoveries published;

14 Disease Teams aim for Human Trial approvals within 48 months from all cell types—embryonic to iPS;

Tens of thousands of job years from funding to date;

Over $100 million of new, net positive state revenue;

Proposition 71's progress honors the initiative mandate of the People of California.

The California Stem Cell Revolution...Promises kept.

Proposition 71, by its 5th anniversary, has launched a veritable California scientific renaissance through a stem cell revolution.

of American higher education—from community colleges to giant research universities—operate as rival duchies and neglected colonies rather than as players on a single team."(2)

Six, Driving Innovative Alliances Between Academic Institutions and Private Biotech Companies. Proposition 71 delivers the financial incentives to break down the barriers between public sector research institutions and private biotech companies to build teams for more powerful and effective translation of stem cell discoveries into treatments. These teams unite the finest public and private sector minds to carry new medical discoveries across the "Valley of Death" – the graveyard of great discoveries that lack the capital and expertise to reach patients. Joint public/private teams enhance the grant or loan applicant's opportunity to "demonstrate convincing evidence" to CIRM's international peer review panels that they can reach human trials within 48 months as required by CIRM's Disease Team RFA." The finest public sector and biotech scientific and developmental expertise join together to provide chronically ill and injured patients real hope within their lifetime.

Seven, Building a Translational Medicine Delivery System, With a Horizontally Integrated Grant and Loan Pipeline. A translational medicine emphasis, with an integrated grant and loan pipeline from point of discovery to treatment of patients, has been constructed by Proposition 71. This replaces the previous national standard of NIH principal investigator grants, a system of fractured, incremental funding, with Proposition 71's broad, integrated funding strategies. Under Proposition 71, funding can carry discoveries through preclinical development, toxicology, preclinical trials and a Phase I human trial. Follow on milestone driven funding can drive the research therapy through Phase II human clinical trials to prove efficacy. With full Board support, President Alan Trounson placed a central focus in the Strategic Plan update on these broad translational grants and loans by raising the 2009 funding for translational grants from $40 million to more than $70 million and Disease Team grants from $60 million to $230 million.

All of this critical scientific progress continues to be dependent on the extraordinary contributions of basic and clinical scientists from outside California who have contributed their time to the Grants Working Group. These remarkable and generous individuals are listed at page 36 of this report. California, indeed the world, owes them thanks for their critical contribution to this medical progress.

Eight, Access for California's Brightest Students to Stem Cell Research Opportunities. "California Dreamin"(3) means real access for California's brightest students to stem cell research opportunities. The CIRM Bridges Program, launched at 28 Cal State Universities and community colleges, connects students to research training at 32 of California's most prestigious universities, research institutes, research hospitals, and biotech firms. Access to opportunity and discovery is created for students from every economic, ethnic, and racial sector of the society through the "bridges" it builds across the entire range of our state's higher educational structure. This provides a gateway to opportunities, in one of the few high growth sectors of the California economy.

Nine, the Massive Push-Pull Research Impact of the Facilities Program. The driving force of long-term, world-class, research facilities is guaranteed by Proposition 71 and the $880,000,000 of donor/institutional matching funds. While Proposition 71 restricted funding of research facilities to 10% ($300 million) of the total authorization, the speed of development and leverage competition directed by the Initiative has lead to $1,180,000,000 in facilities, equipment, and faculty recruitment funds. Proposition 71's initial push to create these research facilities will now generate the long-term funding "pull" from the 2,000 outstanding scientists, clinicians, post-doctorates, and graduate students housed in these facilities, as they capture new, supplemental public and private resources to drive stem cell research and therapy developments.

Ten, Designing A Revenue Positive State Financial Structure. Proposition 71 designed a revenue posi-

tive state financial structure to carry stem cell research almost a decade. To provide time for medical savings to be generated from new therapies and to deliver a revenue-positive financial structure that can propel a 21st Century biotech economy for California, Proposition 71 is structured to generate sufficient new tax revenues under current estimates, to offset any state general fund bond payments through the middle of the 9th program year, before counting any medical savings from new therapies. Over the 35-year life of the Initiative, a conservative estimate of state government medical savings projects a 200 percent payback to California of the entire $3 billion in bond principal and the $3 billion in interest payments on the bonds (over 35 years).

The support of Governor Arnold Schwarzenegger and Treasurer Bill Lockyer have been critical in accomplishing the major allocation of resources to translational medicine to date, in their positive leadership response to the Board's request for $400 million in bond proceeds over the past 12 months.

A New NIH Era – It Takes The Entire Proposition 71 Team. With President Obama's declaration that the NIH would fund embryonic stem cell research, a new era of partnership with the NIH concurrently funding human embryonic stem cell research became possible. To realize on this opportunity, new research ethical standards had to be rapidly developed and processed through the federal public comment process. To achieve a "real time" response on proposed federal guidelines that integrated both policy and practical scientific administrative procedures that would result in rapid and effective federal regulations, the Board established an NIH Guidelines Response Task Force to provide immediate feedback and input to an effort led by Dr. Geoff Lomax and Elona Baum, JD. Melissa King, Executive Director for the Board, managed the Board task force: Dr. Floyd Bloom, Dr. Susan Bryant, Dr. Michael Friedman, Dr. Jeannie Fontana, Dr. Francisco Prieto, Jeff Sheehy, and Sen. Art Torres (Ret.). The agency's proposed guidelines approved by the board were echoed in the deliberations of the Interstate Alliance on Stem Cell Research and the NIH closely reflected these proposals in their final guidelines. This process launched the new era in complementary state and federal funding that promises to accelerate the race to knowledge and potential cures for patients throughout the nation.

Tens of Thousands of Job Years. With $1 billion in funding commitments approved by the Governing Board, by the end of 2009 and over $1 billion in matching funds from donors and institutions, an extrapolation of job creation from prior studies would project tens of thousands of job years will be generated, just by the grants and loans approved to date. Biotech is one of the few high-growth job generators in the current California economy and the jobs that are generated today create a strategic platform that advantages California's opportunity to grow this economic field.

The "End Game Of Life." All of the Governing Board Members, patient advocates, deans, scientists, biotech pioneers and the Agency's scientific and administrative staff started the Proposition 71 mission five years ago with the ultimate hope and goal of lessening human suffering and saving human lives. We knew that this would be a long and challenging process; but in 2009, a short five years later, the first human lives were saved. Michael Fox, a patient of Dr. Catriona Jamieson, described how he viewed his condition, primary myelofibrosis as the "End Game of Life", with his only hope being to find a bone marrow transplant donor. He related how the therapy developed by Dr. Jamieson had saved him from this desperate ending to a productive life. He is part of the first FDA approved human trial for a therapy funded in part by CIRM grants. The second human trial has now started, based on research contributed by CIRM funded scientists; this trial is for Chronic Myelogenous Leukemia.

The patients in these trials could have been from our own families. Once one understands the suffering and nightmares of any family member, it is natural to identify with the suffering and hopes of every patient. We are all part of the human condition. In the great English religious poem, "For Whom The Bell Tolls" by John Donne, the words from four hundred years ago are true today: **"No man is an island, Entire of itself. Each is a piece of the continent, A part of the main...Each man's death diminishes me, For I am involved in mankind. Therefore, send not to know For whom the bell tolls, It tolls for thee."** So let us celebrate every life saved, as Proposition 71 honors the Initiative mandate of The People of California; the Stem Cell Revolution is launched. The Governing Board, whom I represent, and the Agency Staff, is proud to be serving The People of California.

Proposition 71 dissolves the walls blocking scientific collaboration between research institutions and between departments in those institutions.

1 Adelson and Weinberg (2010) The California Stem Cell Initiative: Persuasion, Politics, and Public Science, *Am J Public Health*

2 Gee, Ohio University president

3 The Mamas and The Papas

ALAN TROUNSON, PH.D.

When I look at the additions to our research portfolio over the past year I can only say, "Amazing, we really can get this job done: we can push stem cell based therapies toward the clinic for patients."

What's more, the breadth and variety of ways our grantees are proposing to use stem cells to improve patients' lives goes beyond anything I would have imagined even a year ago. The acceleration of progress in the field is phenomenal. When the first of these preclinical projects, the Early Translational grants, were awarded in April, it was less than two and a half years after CIRM's research grants were first made in February 2007.

In December 2006, when the board adopted our initial strategic plan, the document speculated that by this year we might receive a few applications from researchers who thought they could meet the exacting four-year time frame our Disease Team grants demanded, and maybe have one or two that passed muster with our outside reviewers and the board. But in October when the first Disease Team awards were made, there were 32 applications, and 14 were deemed to have a credible chance of applying to begin a clinical trial in the four-year window. That is several times the level of CIRM's expectations just three years ago.

Altogether CIRM has 22 projects in its translational portfolio. Their variety astounds in the type of cell used and in the disease targeted as well as in the therapeutic tactics. Half are using pluripotent stem cells, seven are using adult stem cells, three are looking at the role of cancer stem cells, and one is seeking to activate endogenous stem cells. Disease targets range from HIVH/AIDS, cancer and sickle cell anemia to stroke, diabetes and heart disease. Six projects are looking to replace damaged cells, eight involve genetically modified cells to correct a genetic error or to introduce disease resistance, four are developing traditional drugs discovered through stem cell research, and four are using combinations of therapies, including two that are using stem cells to carry cancer-killing agents to high-risk inoperable tumors.

Disease Teams Unite to Conquer The Disease Team grants drew together many robust multi-institution collaborations. Boundary-crossing teams like these don't assemble easily but can really accelerate a project. Teams attempting novel therapies often require collaborations involving leading innovators in multiple fields. Let me highlight just a couple.

To try to cure the blindness caused by macular degeneration, Mark Humayun, an ophthalmologic biomedical engineer and neurobiologist at the University of Southern California, has teamed up with David Hinton, a retinal researcher at USC; Dennis Clegg, a cellular and developmental biologist at UC Santa Barbara; and Peter Coffey, a cellular therapeutics expert at University College London. Coffey's work will be funded through the Medical Research Council of the United Kingdom through one of CIRM's collaborative funding partnerships, which are another major achievement for the agency this year (see story on page 13). The team will be maturing embryonic stem cells into retinal pigmented epithelial cells, which in animal studies have been shown to nurture the growth of a healthy macula in the back of the eye.

Two teams have set out to tackle HIV/AIDS by combining stem cell therapy with gene therapy. Physicians have long noted that some people infected with HIV never get sick with AIDS, and more recently investigators have observed that a patient in Berlin who had bone marrow transplanted with

a variant gene resulted in a new immune system that was resistant to HIV infection. Both CIRM-funded teams plan to genetically alter patients' own blood-forming adult stem cells so they mimic the cells given the Berlin patient.

Both HIV groups have also teamed up with industry partners to help with the gene modifications. Irvin Chen at UC Los Angeles has brought on Geoff Symonds of Calimmune as a co-principal investigator; they will be using the company's RNA interference technology. RNAi has been shown to be a powerful tool to alter gene activity. John Zaia at City of Hope National Medical Center has contracted with Sangamo BioSciences to use that firm's "zinc finger" technology for accurately manipulating genes. We could expect some very interesting spillover developments from these rich new collaborations.

Full Pipeline of Research Still Critical As excited as I am about our new translational research portfolio, I am equally proud that we have continued to fund the full pipeline of research. Many fundamental questions in stem cell science remain unanswered. The 12 Basic Biology awards that the board approved in August will go a long way toward answering some of those questions. Another 52 Basic Biology applications were sent to our outside review panel in December. The group will formally deliberate on these proposals in February 2010.

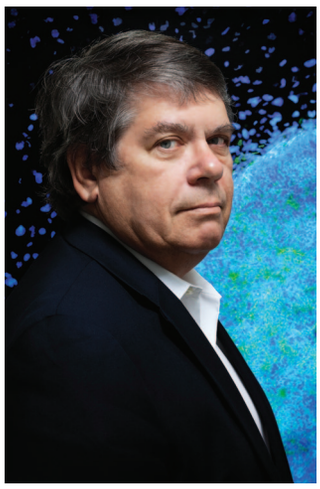
Maintaining a robust pipeline for regenerative medicine sometimes means filling very specific gaps in the field. Our Stem Cell Transplantation Immunology awards target such a gap: the need to avoid immune rejection and the ultimate destruction of donor cells. We received 44 applications for this round of funding, also in December. These applications propose a number of innovative approaches to the induction of immune tolerance.

At its December meeting our board approved proceeding with a request for applications (RFA) for a second round of Early Translational awards. This one is slated for up to $80 million in grants. The concept approval for a second RFA for Tools and Technology will also be recommended to the board early in 2010.

As these technical tool and translational grants move CIRM's program closer to the clinic, we are continuing to look for ways to forge stronger ties with industry, which has the expertise to bring products to the market. We expect that our loan program, which launched with the first round of Disease Team awards, will help in this regard.

Personnel Pipeline Key, Too CIRM awarded its very first grants in April 2006, not for direct research but for training. However, because the postdoctoral and clinical fellows funded by those grants are the working engine of most labs, that round of funding helped produce more than 280 of the over 400 scientific papers published by the end of 2009 with CIRM grants. Many of those 280 papers involved CIRM funding in addition to the training grant, but the number of papers with CIRM trainees shows how critical these grants are to productivity. Because of this, CIRM funded a second round of training grants in 2009 that eventually awarded 17 institutions more than $45 million for this effort.

Also this year, we launched a new effort to augment California's intellectual capital in stem cell science at another key point in the career pathway. Mid-career scientists are often at their most productive and creative and many are poised and ready to take a leadership role. CIRM's mission could be accelerated by bringing some of these brightest-at-their-best scientists to the state, which is the goal of the new CIRM Research Leadership awards. These grants will provide guaranteed salary support and other significant inducements.



I was pleased to initiate a very special training program, Bridges to Stem Cell Research, which draws young undergraduate and master's students from community colleges and Cal State universities. Many of these young scientists come from disadvantaged communities, but they now have a chance to participate in stem cell research by receiving specialized training and internships at major research centers. They are a very impressive new group of motivated young scientists.

The board approved more than $23 million for 16 community colleges and state universities to support the development of a scarce workforce that is now a limiting factor for the state's biotech industry.

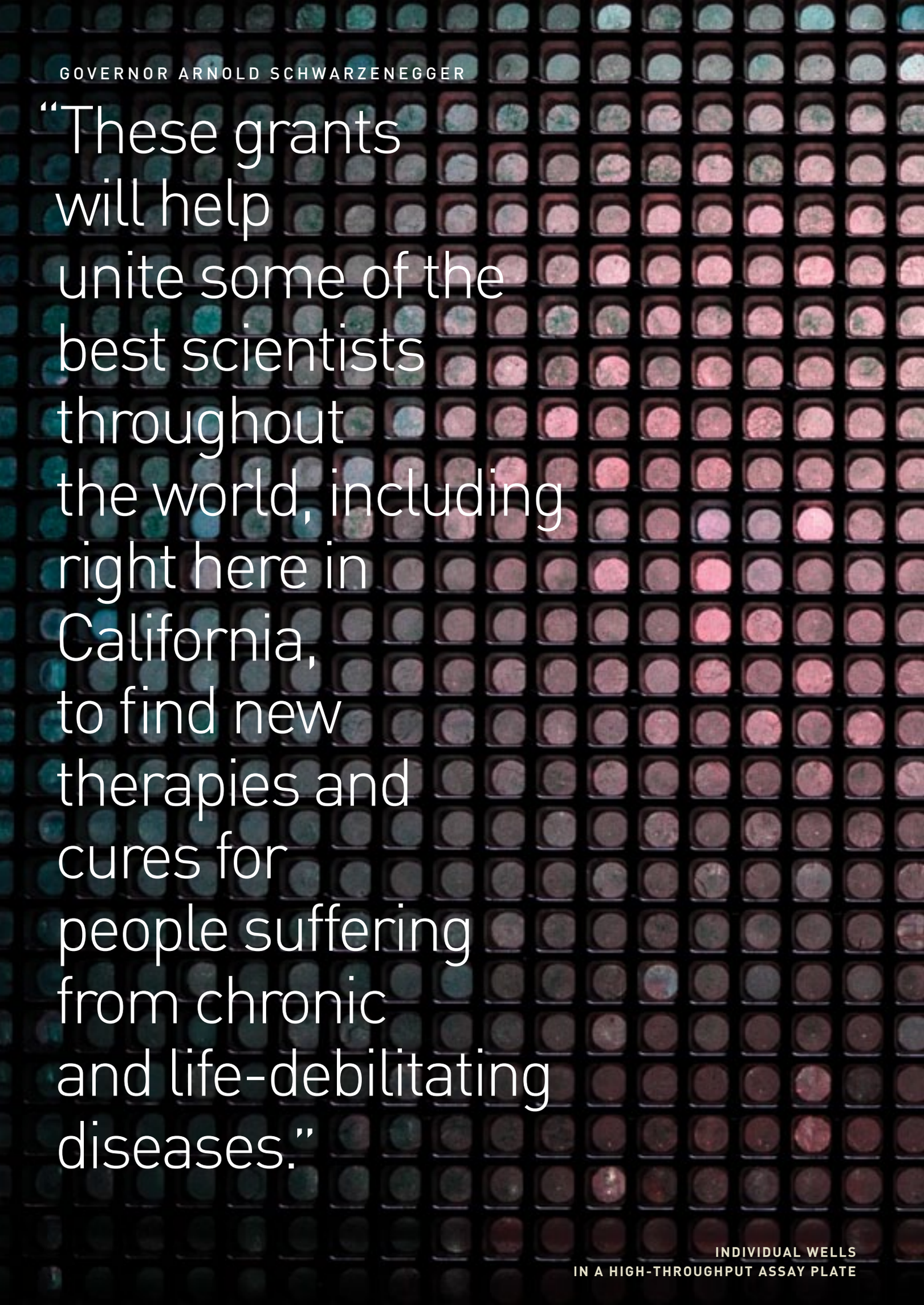
I want to acknowledge CIRM staff—both our crackerjack science team and our very effective administrative and management teams. Their work enabled the accomplishments made in 2009. Without them the tangible hope for cures that we are facilitating would still be distant dreams.

We are all motivated in this work by the patients we strive to serve as we honor the will of the California voters who put their confidence behind this bold initiative for accelerating science. Thank you for your support.

As excited as I am about our new translational research portfolio, I am equally proud that we have continued to fund the full pipeline of research.

GOVERNOR ARNOLD SCHWARZENEGGER

"These grants will help unite some of the best scientists throughout the world, including right here in California, to find new therapies and cures for people suffering from chronic and life-debilitating diseases."



INDIVIDUAL WELLS
IN A HIGH-THROUGHPUT ASSAY PLATE

The Bridges to Stem Cell Research Awards

THE 16 BRIDGES PROGRAMS, AWARDED IN 2009, along with the 12 educational partners, provide undergraduate and masters-level students the coursework and laboratory experience needed to staff California's expanding stem cell research laboratories in both industry and academic organizations. They also fill a void forecast by BayBio and the California Public Policy Institute who predicted widespread shortage of college-educated and technically trained workers to meet the burgeoning stem cell industry demands.

- Internship Hosts
- Bridges Participants

BRIDGES PROGRAMS

Berkeley City College
California Polytechnic State University, San Luis Obispo
California State Polytechnic University, Pomona
California State University, Channel Islands
California State University, Fullerton
California State University, Long Beach
California State University, Northridge
California State University, Sacramento
California State University, San Bernardino
California State University, San Marcos
City College Of San Francisco
Humboldt State University
Pasadena City College
San Diego State University
San Francisco State University
San Jose State University

EDUCATIONAL PARTNERS

California State University, Los Angeles
Citrus College
East Los Angeles College
Irvine Valley College
Mira Costa College
Moorpark Community College
Moreno Valley College
Oxnard Community College
Riverside Community College
San Bernardino Valley College
San Diego Miramar College
Ventura Community College

"The Bridges to Stem Cell Research Awards not only train tomorrow's scientists, but also gives people like me, a woman of color and first generation college student, the ability and opportunity to reach my highest potential."

MARISA LEAL, SAN FRANCISCO STATE UNIVERSITY
BRIDGES PROGRAM PARTICIPANT.

news at CIRM
MOVING TOWARD THE CLINIC

In naming Proposition 71 The California Stem Cell Research and Cures Act its authors emphasized the ultimate goal of delivering life-saving regenerative medical treatments and cures to the people of California and the world.

Each incremental breakthrough made by a CIRM-funded researcher brings us closer to achieving these therapies for the more than 70 currently incurable diseases and injuries that could be addressed by stem cell science.

Of the more than $1 billion committed by CIRM for research funding, the largest portion is for research that bridges basic discoveries to clinical applications. The Early Translation and Disease Team awards granted in 2009 together provide $300 million for such projects.

EARLY TRANSLATIONAL AWARDS

The Early Translational grants provided more than $70 million to fund 16 grants focused on moving basic research toward human clinical trials and are an important part of CIRM's strategy to advance the best basic research into clinical application. These grants were given to either advance molecules or cell types with high potential for use in regenerative medicine or to address a bottleneck in the development of new therapies.

In 2009, the Early Translational grants funded research that could help advance therapies for diseases like type 1 diabetes, Parkinson's disease, arthritis and blood diseases in infants. Underscoring the importance of this leg of CIRM's grant strategy, the Early Translational grants are expected to be awarded annually.

DISEASE TEAM AWARDS

CIRM's Disease Team Awards launched an innovative model for organizing interdisciplinary research teams within California and around the world. These awards encourage the integration of basic, translational and clinical research in an innovative team approach that has the potential to advance therapies into the clinic more rapidly.

Recipients of Disease Team Awards are expected to file a request to begin clinic trials with the U.S. Food and Drug Administration in just 48 months—or less.

CIRM President Alan Trounson said the pace of the Disease Team projects stands in contrast to the decade or more that's usually required to reach clinical trials. "By encouraging applicants to form teams composed of the best researchers from around the world we think CIRM will set a new standard for how translational research should be funded," he said. Notably, eight teams have significant participation from pharmaceutical or biotech industry scientists who are well versed in the clinical and regulatory path of drug development.

In October, CIRM's Governing Board awarded 14 Disease Team Awards that have the potential to lead to breakthroughs for up to 11 different diseases including several types of cancer, HIV/AIDS, type 1 diabetes, stroke, ALS, sickle cell anemia and a rare genetic skin disorder, epidermolysis bullosa. Advancing a therapy or cure for any one of these diseases would be an unprecedented medical breakthrough.

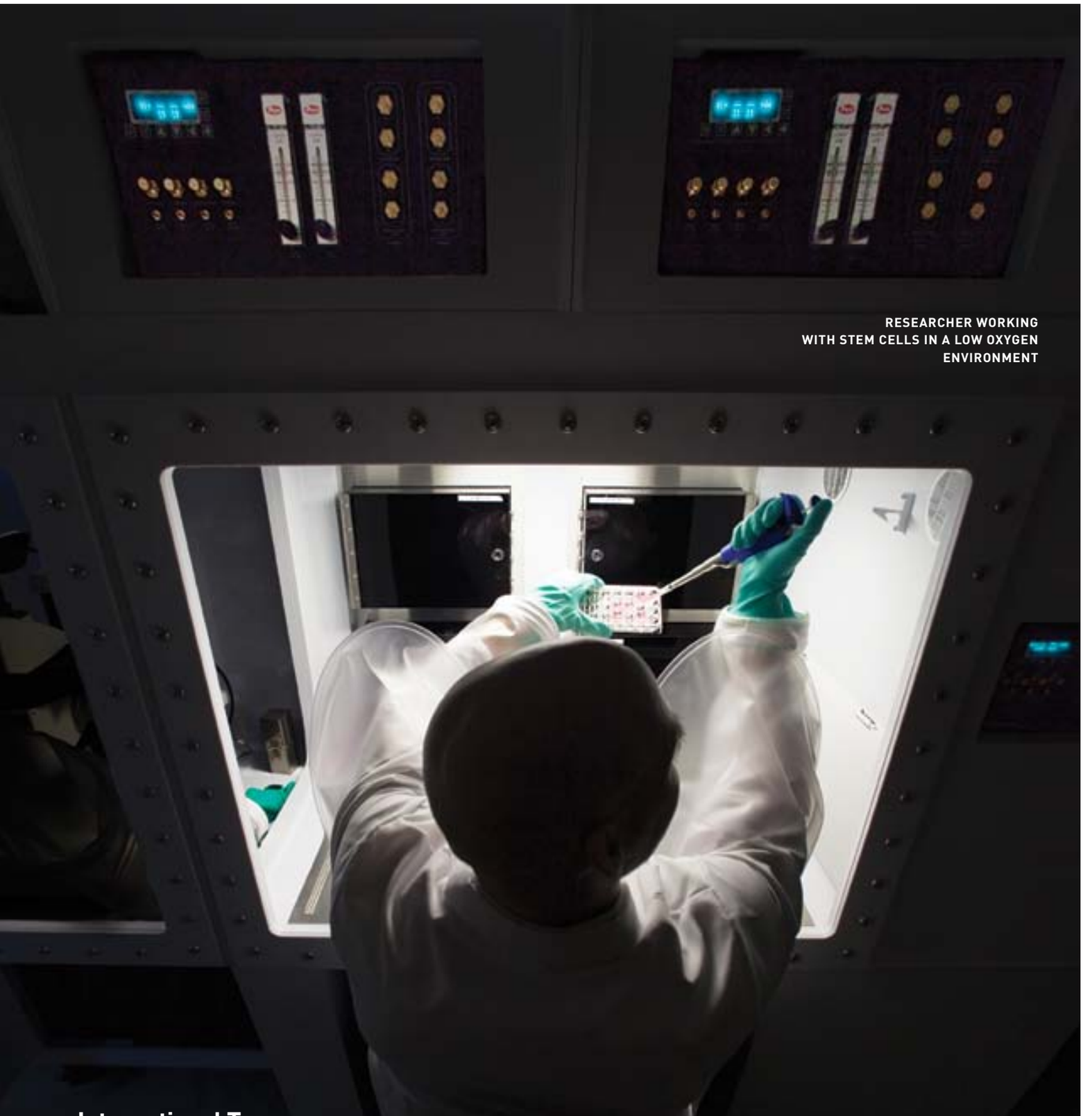
The grants were awarded to research spanning three approaches: embryonic stem cells, adult stem cells and applications of stem cells to develop or deliver traditional small molecule therapies.

Researchers in California had the choice of building their teams with scientists from within the state, or augmenting the teams with additional expertise from CIRM's international Collaborative Funding Partner program. Four of the succesful teams had partnerships with Canadian or U.K .scientists, with the two countries committing approximately $35 million and $8 million, respectively.

One award went to a for-profit company—Novocell, which is developing a therapy for type 1 diabetes—and will take the form of a loan. Robert Klein, chairman of the CIRM Governing Board said, "In providing stem cell funding in the form of loans, CIRM is able to fund more science and make a more significant impact on the speed of bringing new stem cell-based therapies to the people of California and the world."

MORE ON THE WEB

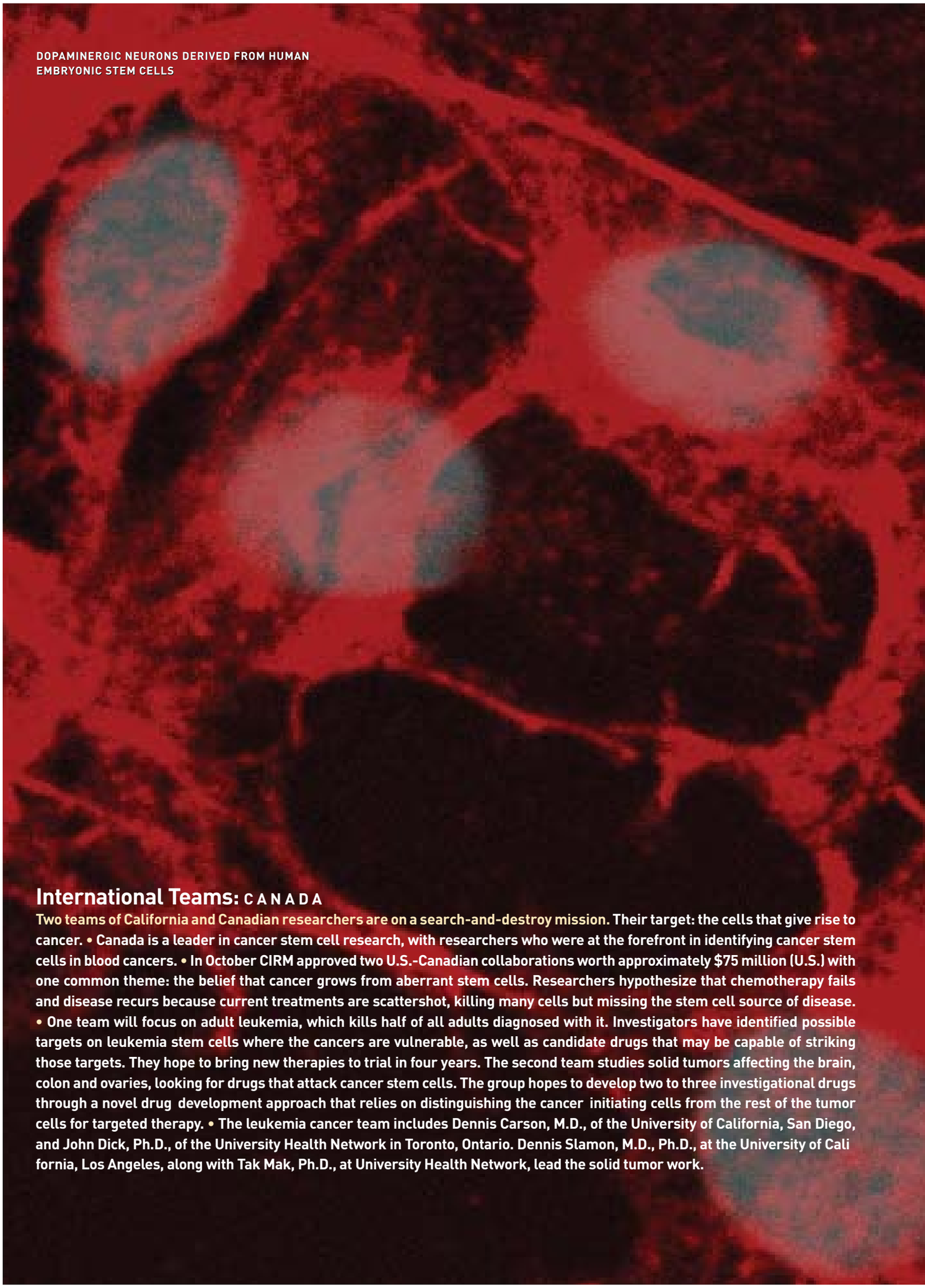
Read summaries of all Disease Team Award research projects



RESEARCHER WORKING WITH STEM CELLS IN A LOW OXYGEN ENVIRONMENT

International Teams: REACHING ACROSS BORDERS

CIRM is reaching across the continent and across oceans to bring together the world's leading stem cell investigators. • This year, the Maryland Technology Development Corporation, the Spanish Ministry of Science and Innovation, the Chinese Ministry of Science and Technology and the German Federal Ministry of Education and Research each laid the foundation for collaborations with California researchers under new agreements brokered by CIRM. Those four join the Japan Science & Technology Agency, Canada's Cancer Stem Cell Consortium, the state of Victoria in Australia and the Medical Research Council in the United Kingdom in signing agreements that make it easier for researchers in California to collaborate with leaders in stem cell research around the world. • "One of CIRM's primary goals is to accelerate the field of stem cell research as a whole," said Dr. Alan Trounson, Ph.D., President of CIRM. "In some instances, we can do this more effectively through collaborations that involve the best scientific endeavors, regardless of geography." • The agreements will ease collaborations between California scientists and other researchers. With this broader pool of expertise, teams submit joint applications for funding in specific research areas. When an application is approved, CIRM funds the California team members, and the other sponsoring institution funds scientists from their locales. • Already Canada has committed approximately $35 million (U.S.), the state of Victoria, Australia has committed $5.4 million (U.S.) and the United Kingdom has committed roughly $8 million to fund those portions of research taking place in the United Kingdom as part of jointly collaborative teams.



DOPAMINERGIC NEURONS DERIVED FROM HUMAN EMBRYONIC STEM CELLS

International Teams: CANADA

Two teams of California and Canadian researchers are on a search-and-destroy mission. Their target: the cells that give rise to cancer. • Canada is a leader in cancer stem cell research, with researchers who were at the forefront in identifying cancer stem cells in blood cancers. • In October CIRM approved two U.S.-Canadian collaborations worth approximately $75 million (U.S.) with one common theme: the belief that cancer grows from aberrant stem cells. Researchers hypothesize that chemotherapy fails and disease recurs because current treatments are scattershot, killing many cells but missing the stem cell source of disease. • One team will focus on adult leukemia, which kills half of all adults diagnosed with it. Investigators have identified possible targets on leukemia stem cells where the cancers are vulnerable, as well as candidate drugs that may be capable of striking those targets. They hope to bring new therapies to trial in four years. The second team studies solid tumors affecting the brain, colon and ovaries, looking for drugs that attack cancer stem cells. The group hopes to develop two to three investigational drugs through a novel drug development approach that relies on distinguishing the cancer initiating cells from the rest of the tumor cells for targeted therapy. • The leukemia cancer team includes Dennis Carson, M.D., of the University of California, San Diego, and John Dick, Ph.D., of the University Health Network in Toronto, Ontario. Dennis Slamon, M.D., Ph.D., at the University of Cali fornia, Los Angeles, along with Tak Mak, Ph.D., at University Health Network, lead the solid tumor work.

news at CIRM
BUILDING THE BASE

Getting from stem cell research to cures requires a robust pipeline of scientific ideas and talent. This pipeline will ensure that the best scientific minds are engaged across a spectrum of academic and industry settings and that we are pursuing the answers in cellular biology that will drive clinical applications of stem cells.

THE NEXT GENERATION OF STEM CELL SCIENTISTS

CIRM has invested more than $106 million to build California's human capital through programs that train the next generation of scientists and laboratory technicians. In 2009 alone, CIRM directed $69 million toward training and developing the state's stem cell research workforce.

Through 16 Bridges to Stem Cell Research Awards, CIRM is engaging undergraduate and masters-level students in stem cell science. The Bridges program funds lecture and laboratory courses, internship placements and mentoring activities to support students in their research progress and career opportunities. Graduates of these programs will have the expertise needed to contribute to California's expanding stem cell research labs in both industry and academic settings.

Marisa Leal, a Bridges trainee in the San Francisco State program, said she hopes to earn an M.D., Ph.D. and develop therapies for cardiovascular disease. "The Bridges to Stem Cell Research Awards not only train tomorrow's scientists, but also give people like me, a woman of color and first-generation college student, the ability and opportunity to reach my highest potential."

In 2009, CIRM also funded the work of graduate and postdoctoral students and clinical fellows working in stem cell research labs through the Research Training Program II. Recipients of CIRM's first Research Training grants, allocated in 2006, were extremely productive, contributing to more than two-thirds of research papers published with CIRM funding. The most recent training grants funded 17 California institutions, supporting programs that encourage young researchers to pursue a career in stem cell science. By providing them with funding to pursue stem cell research projects, CIRM has created a highly productive and focused group of researchers with the training they need to advance the field and build an extensive and diverse pipeline of world-class talent.

CIRM also supported efforts at the state level to advance legislation that develops California as a fertile ground for stem cell science to take hold and flourish. In October, Governor Arnold Schwarzenegger signed SB 471, the California Stem Cell and Biotechnology Education and Workforce Development Act of 2009. The legislation sets expectations for CIRM to collaborate with the California Department of Education and the biotechnology industry to incorporate stem cell and biotechnology into existing science and career development programs at the high school and college level.

THE ROLE OF BASIC RESEARCH

Work by basic researchers seeking to understand stem cell biology feeds an early-stage pipeline of new research ideas. Their discoveries into basic mechanisms of stem cell biology directly feed into work by scientists who use those discoveries to further their work toward cures. CIRM's Basic Biology Awards, planned annually, fund scientists whose discoveries will reveal the fundamental processes of stem cells—knowledge that is essential to generate new ideas that will drive therapies for patients.

In 2009 CIRM funded 12 Basic Biology awards at five California institutions worth a total of $16 million. Included in these grants is one that seeks to turn undifferentiated human stem cells into differentiated neurons that could replace those damaged by Parkinson's disease in the brain. Another is investigating the cellular mechanisms that drive reprogramming in order to find ways to develop iPS cells on a large scale for use in regenerative medicine, individualized medicine and drug discovery.

We can realize the full potential of stem cell science only through the talent and innovation of scientists who dedicate themselves to this area of research. By educating the next generation of scientists we will continue to build a base from which this vital industry can continue to grow in California. And by funding basic research we advance our position as a leading international hub of stem cell science. Supporting basic research is also a good investment: The National Institutes of Health has estimated that each dollar invested by NIH stimulates $2.50 of economic activity.

MORE ON THE WEB

See a video with Bridges recipients at San Francisco State University

PROGRESS AND PROMISE IN TREATING NEUROLOGICAL DISEASES

Maggie, a former marathon runner, was diagnosed in 2006 with multiple sclerosis—a disease whose symptoms progress from relatively mild, such as the limb numbness she experiences, to severe, such as paralysis or loss of vision.

"My hope is that there is a cure by the time my children might have symptoms," says Maggie, a 35-year-old poet and teacher living in Texas. She asked that her last name and hometown not be used due to potential employer discrimination. Some employers, she says, do not want to hire someone they think will become increasingly disabled.

Millions of Americans whose lives are touched by neurological disease, like MS, Alzheimer's disease, Parkinson's disease or spinal cord injury, share Maggie's hope. These disorders are among the most hotly pursued by stem cell researchers around the world and in California. Of CIRM-funded research projects that target a particular disease area, 31 percent focus on neurological disorders.

SUPPORTING THE SURVIVORS

One early concern about stem cell–based therapies for neurological disease was one of functionality. Even if embryonic stem cells can mature into an appropriate nerve type, how can they ever replicate the complex connections of the nerves carrying memories of your children's names or your spouse's face?

Because of the intricacy of neural connections, Theo Palmer, Ph.D. associate professor of neurosurgery at Stanford University, expects transplanted stem cells will most likely first be used to support remaining cells rather than replace function. "This will improve or extend the quality of life," Palmer says, even if they don't cure the disease entirely.

A Disease Team led by researchers at the Salk Institute for Biological Studies in La Jolla proposes to replace the support cells surrounding the neurons damaged in ALS. Rather than replacing the function of the damaged cells, which would require forming new connections, this approach would protect remaining neurons from damage. The strategy has been effective in animal models.

Likewise, the stroke Disease Team led by Stanford University researchers is anticipating that inserted stem cells would protect cells that survived the stroke rather than replacing those that were lost. Another CIRM-funded project has early evidence in mice that an approach using embryonic stem cells could protect nerve cells in people with MS.

DISEASE IN A DISH

In some cases stem cells may directly treat a neurological disease. In others, they may prove most useful for understanding the disease and finding new drugs. Fred Gage, Ph.D. at the Salk Institute for Biological Studies developed a model of ALS in a lab dish and hopes to use that model to test drugs to treat the disease. Without stem cells there was no way to model the disease and study it directly in the lab.

At the University of California, San Diego, Lawrence Goldstein, Ph.D. has been using a similar approach to study the origins of Alzheimer's disease. He wants to know if any existing drugs can alter the progression of the disease in his laboratory model.

"We can use stem cell lines to test all known drugs for off-label use. It's a long shot, but it is one worth taking," Goldstein says. "If we can find a drug that works, that would be preferable to transplanting cells into the brain." A team at the Parkinson's Institute in Sunnyvale, CA has a similar goal, using stem cells to screen drugs that improve the functionality of cells showing signs of Parkinson's disease in a dish.

THE PACE OF PROGRESS

For all its challenges, Arnold Kriegstein, M.D., Ph.D., director of the Eli and Edythe Broad Center of Regeneration Medicine at the University of California, San Francisco, predicts that stem cell transplants will one day be used to cure disease.

"I don't expect any homeruns from the early trials. The homeruns will come later. We all need to be prepared for that. These trials are about the limits of the current technology," Kriegstein says.

Though the pace of research may mean that some cures are years away, Maggie hopes her children will not endure the symptoms of MS—or hide the fact that they have it—the way she has had to do. "I am hoping for a cure for MS for the next generation."

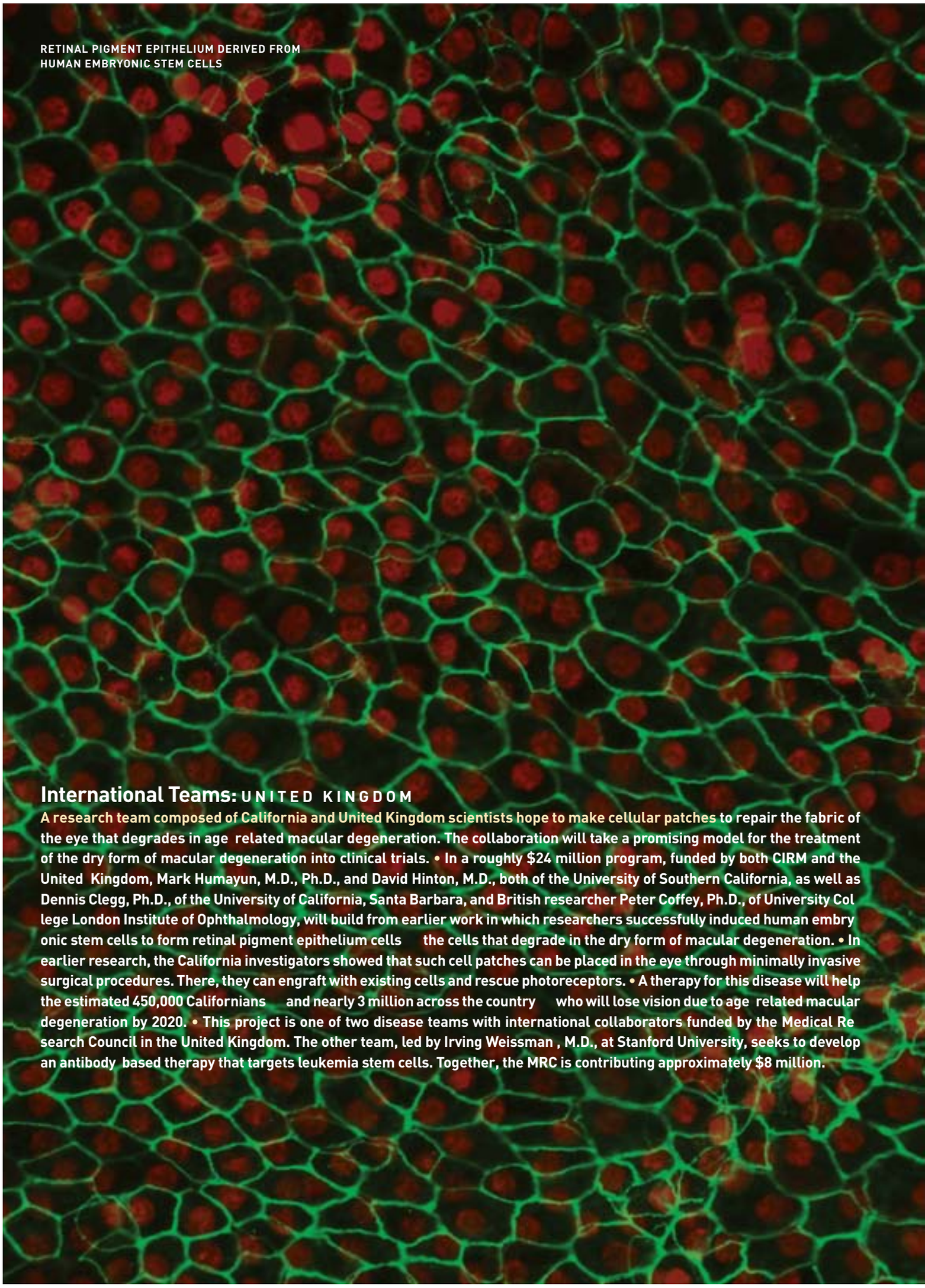
MORE ON THE WEB

Watch an interview with Fred Gage about his ALS work

RACKS OF EXPERIMENTS AWAITING ANALYSIS
BY THE HIGH THROUGHPUT ROBOT

International Teams: AUSTRALIA

Every promising stem cell treatment faces the same hurdle: assuring the U.S. Food and Drug Administration that the cells cannot run amok. Developing tools to eliminate any undifferentiated stem cells that are capable of going astray is at the heart of one of four new collaborations between California investigators and researchers in Australia. • The col laborations announced in May grew from an agreement signed last year by CIRM and the state of Victoria, the heart of Australia's stem cell research community. • Jeanne Loring, Ph.D., of the Scripps Research Institute in La Jolla, in partnership with Andrew Laslett, Ph.D., of the Commonwealth Scientific and Industrial Research Organization, aims to design a way to rigor ously select and destroy unwanted cells before stem cell transplantation. • THE OTHER PARTNERSHIPS ARE: Evan Snyder, M.D., Ph.D., of Burnham Institute of Medical Research in La Jolla with Clare Parish, Ph.D., of Florey Neurosciences Institutes and Colin Pouton, Ph.D., of Monash Institute of Pharmaceutical Sciences in Victoria, for research into Par kinson's disease; Justine Cunningham, Ph.D., of Novocell Inc. in San Diego, in partnership with Andrew Elefanty, M.D., Ph.D., and Ed Stanley, Ph.D., both of the Monash Immunology and Stem Cell Laboratories, to develop tools for diabetes treatment that recognize and eliminate undifferentiated stem cells that may form benign growths; and Frank LaFerla, Ph.D., of the University of California, Irvine, in cooperation with Richard Boyd, Ph.D., of Monash Immunology and Stem Cell Laboratories, to study a stem cell therapy for Alzheimer's disease and find ways to prevent immune rejection of the new cells without the prolonged use of immunosuppressants.



RETINAL PIGMENT EPITHELIUM DERIVED FROM
HUMAN EMBRYONIC STEM CELLS

International Teams: UNITED KINGDOM

A research team composed of California and United Kingdom scientists hope to make cellular patches to repair the fabric of the eye that degrades in age related macular degeneration. The collaboration will take a promising model for the treatment of the dry form of macular degeneration into clinical trials. • In a roughly $24 million program, funded by both CIRM and the United Kingdom, Mark Humayun, M.D., Ph.D., and David Hinton, M.D., both of the University of Southern California, as well as Dennis Clegg, Ph.D., of the University of California, Santa Barbara, and British researcher Peter Coffey, Ph.D., of University Col lege London Institute of Ophthalmology, will build from earlier work in which researchers successfully induced human embry onic stem cells to form retinal pigment epithelium cells the cells that degrade in the dry form of macular degeneration. • In earlier research, the California investigators showed that such cell patches can be placed in the eye through minimally invasive surgical procedures. There, they can engraft with existing cells and rescue photoreceptors. • A therapy for this disease will help the estimated 450,000 Californians and nearly 3 million across the country who will lose vision due to age related macular degeneration by 2020. • This project is one of two disease teams with international collaborators funded by the Medical Re search Council in the United Kingdom. The other team, led by Irving Weissman , M.D., at Stanford University, seeks to develop an antibody based therapy that targets leukemia stem cells. Together, the MRC is contributing approximately $8 million.

SIGHTS ON A CURE FOR MACULAR DEGENERATION

Painter Virginia Knepper Doyle's creativity and passion as a nature enthusiast have taken her art to audiences from her home in Tiburon, near San Francisco, to New York and Paris.

What her admirers may not know is that over the last 11 years Doyle has lost much of her central vision to macular degeneration. Since her diagnosis, Doyle has left Impressionism in favor of abstract art and has seen her critical acclaim grow.

"I was trying to be somebody else," she said. "The real me came out, and I didn't care if I made mistakes."

This professional success comes at a price; Doyle has difficulty reading and recognizing faces and can no longer drive.

Doyle misses her lost independence and is looking to stem cell scientists for hope. With good cause: Many experts consider macular degeneration to be a disease for which stem cells could provide relief sooner rather than later.

VANISHING CELLS

According to the National Eye Institute, more than 1.7 million Americans have the disease, in which cells in the back of the eye slowly die. These cells, called retinal pigmented epithelia, or RPE cells, form a nourishing blanket over the light-collecting cells of the retina.

In the early, or "dry," stage of the disease, the RPE cells at the center of a person's vision, called the macula, atrophy, leaving a noticeable distortion in the visual world. In the second and more severe stage, known as "wet" macular degeneration, abnormal blood vessels begin to grow through the macula. These vessels can leak and lead to scarring and eventual vision loss.

A PERMANENT SOLUTION

Currently, no treatment for dry macular degeneration exists. Abnormal blood vessel growth of wet macular degeneration can be arrested with regular injections of expensive anti-angiogenic drugs directly into the eye.

Researchers have struggled to find a more permanent solution, including two surgical procedures, both of which involve relocating a patient's own RPE cells or macula. Either way, there are not enough RPE cells to work with in a patient's eye. And there are risks.

"Because you cut the retina, 20 to 30 percent of the time, the retina completely detaches," said Mark Humayun, M.D., professor of ophthalmology and biomedical engineering at the University of Southern California, at a talk to CIRM's Governing Board in April. "You're left with poorer vision than you started."

BUILDING A BETTER BLANKET

Several CIRM-funded researchers have the goal of coaxing stem cells to form a blanket of RPE cells for transplantation. At USC, Humayun received a disease team award for work using embryonic stem cells as a starting point.

Martin Friedlander M.D., Ph.D., professor of cell biology at the Scripps Research Institute near San Diego and Gabriel Travis, M.D., professor of ophthalmology and biological chemistry at the University of California, Los Angeles, have received Early Translational grants to create RPE cells by reprogramming a patient's own skin cells into induced pluripotent stem (iPS) cells. These cells possess a versatility similar to embryonic stem cells and thus should have the capacity to form RPE cells.

Both groups hope to be in human clinical trials within the next few years.

Work pioneered by a collaborator on Humayun's disease team award at University College London shows evidence that a procedure involving transplanting stem cell–derived RPE cells may work. Ophthalmology professor at University College Pete Coffey, Ph.D., placed the RPE cells derived from human embryonic stem cells on a disk as thin as cling film, and implanted the disk into a pig's retina during a procedure that took 40 minutes. These transplanted RPE cells properly nourished the light-collecting cells of the retina. Coffey and his research group hope to treat patients by 2011.

Busy with her successful art career, Doyle may not have the time to follow the day-to-day successes and setbacks of stem cell–based therapies. But that doesn't mean she's not eager for a cure.

"I can't wait," she said. "I just wish (stem cell research) will succeed with all diseases."

MORE ON THE WEB

See a video featuring Mark Humayun discussing his research

news at CIRM

BASIC RESEARCH BRINGS CLINICAL HOPE

Robert Blelloch, M.D., Ph.D., a stem cell biologist at the University of California San Francisco, has been trying to understand how a cell hangs onto its identity over time.

Here's the dilemma: Each cell in your body shares the same DNA with every other cell. So how does a heart muscle cell know to contract rhythmically, while an immune cell recognizes and attacks foreign invaders and groups of neurons form complex networks in the brain? Then, if our neurons and our heart cells share the same DNA, why don't neurons start beating? Or grow hair?

These questions are more than a dusty academic curiosity. The answers could mean new therapies for diseases like diabetes, spinal cord injury, HIV/AIDS and neurodegenerative diseases—they could also mean better ways of reprogramming adult cells into therapeutically useful embryonic-like stem cells.

Now, Blelloch and other scientists are getting excited about tiny molecules called microRNAs that seem to play a major role in directing cells from one identity to another and in holding cells in their eventual fate. They may in part explain how two cells with identical DNA could become neurons or heart muscle and why those neurons don't beat. "People believe they could be very powerful molecules that we can get a handle on and use to manipulate cells," Blelloch says.

With such a seemingly broad role in controlling a cell's fate, microRNAs may represent a new opportunity to understand stem cells and control them in laboratory research and experimental therapies. This potential isn't lost on stem cell researchers in California and around the world. In 2009, CIRM grantees alone published 11 papers linking microRNAs to stem cell biology and to possible future therapies.

BUILDING THE HEART

One newly discovered role for microRNAs is in guiding the development of the heart. Deepak Srivastava, M.D., director of the Gladstone Institute of Cardiovascular Disease, has uncovered specific microRNAs that can lead embryonic stem cells to become three different kinds of cells of the cardiovascular system. Getting stem cells to differentiate into a cell type of choice is one of the most difficult problems facing stem cell researchers.

In his clinical practice, Srivastava cares for children with heart defects that are a direct result of the failure of cardiac stem cells to properly differentiate. He hopes his discovery can help make sense of these diseases and eventually find ways to use stem cells to create heart tissue to treat cardiac defects in children and restore cardiac function in adults.

HOLDING STEM CELLS IN CHECK

Blelloch's lab at UCSF has found that a set of stem cell-specific microRNAs are critical for an important property of stem cells: their ability to make new copies of themselves, known as self-renewal. This discovery has implications for scientists' ability to create induced pluripotent stem cells—adult cells that are reprogrammed to act like embryonic stem cells. The standard method of creating these cells is to insert genes into the DNA of an adult cell such as skin. According to Blelloch's research published early in 2009 and funded by CIRM, introducing microRNAs into a cell could be an alternative way of transforming cells, one that is safer and more efficient, and does not rely on modifying the cells genetically.

A PRACTICAL SOLUTION

One reason scientists are excited about microRNAs is their practicality. "They can potentially someday be delivered like a drug," Blelloch says. MicroRNAs are active for only a period of time, so they behave more like drugs and dont require making permanent changes to a cell's DNA. Yet one or two of these powerful molecules may be enough to make a dramatic impact on a cell's state.

Blelloch says it may be possible someday to use them to drive stem cell processes within the body without the need for introducing new cells: for instance, giving microRNA to a patient with a damaged liver to temporarily activate endogenous stem cells in the organ. But using microRNAs as therapies will require more knowledge about how they work, and the quest to understand them is just beginning.

MORE ON THE WEB

See a video about Blelloch's work using microRNA to reprogram cells

NEURONS DERIVED FROM EMBRYONIC STEM CELLS

CIRM Workshop: AUTISM

Autism is a disorder of profound puzzles. No one knows its cause. No one knows what goes wrong inside the cells of people who have it. No one even knows how many varieties of autism there are and whether and how those varieties are related to one another. • Induced pluripotent stem cells (iPS) grown from the tissue of people with autism may provide clues to these puzzles, participants at a CIRM autism workshop in May concluded. iPS cells are generated by persuading fully differentiated cells to behave like pluripotent embryonic stem cells, that is, cells capable of turning into numerous other cell types. • In culture, the iPS cells could help resolve many fundamental questions about the underlying biology of autism. Once matured into neurons, cells could be subject to a battery of tests and environmental insults in an attempt to mimic the development of the disease. And where signs of autism develop in culture, further rounds of testing could reveal how to return those cells to normal function providing a possible therapy for the disorder. • The panel recommended that these cell culture studies be conducted in parallel with efforts to categorize the many varieties of autism in order to correlate the cellular changes with the way autism manifests in individuals.

"When we say that the goal of this funding is to get to the clinic, these are not just well-placed bets. These are carefully considered projects."

JEFF SHEEHY, HIV/AIDS ADVOCATE,
MEMBER OF THE CIRM GOVERNING BOARD

SPOTLIGHT ON DISEASES

At each board meeting, a Spotlight on Disease presentation features patients, clinicians and researchers speaking about THE HOPE OF STEM CELL RESEARCH. These are their stories...

A type of stem cell appears to be the Achilles' heel in some forms of blood cancer including LEUKEMIA. Since 1937, some researchers have hypothesized that cancers arise from certain of the body's stem cells, the cells primed to make a variety of other cell types.

IF TRUE, CANCER MAY BE MOST VULNERABLE THERE, AT ITS SOURCE. The problem was, "For a long time the tools didn't exist to really examine this hypothesis," said Dr. Catriona Jamieson, M.D., Ph.D., an assistant professor at the University of California, San Diego.

But a recently completed phase 1 trial for a drug created by a San Diego-based company, TargeGen Inc., and investigated in Jamieson's lab, demonstrates that at least in the case of polycythemia vera, this focus on the stem cells, where the body first stumbled into disease, holds promise.

Phase 1 studies test a treatment's safety, not it's effectiveness. The question of whether the drug works isn't addressed until a Phase II trial, after it is proven to be safe at a range of doses. So Jamieson, the director of the stem cell research program at the Moores UCSD Cancer Center, wasn't expecting symptom improvement when the drug entered these early trials in patients with advanced disease. She knew it worked in tissue culture. Her laboratory had proved its efficacy in animal studies. But its success in humans wouldn't be tested unless phase 1 ended successfully.

But to Jamieson's surprise, the phase 1 trial improved the health of all 59 trial patients, many dramatically. Myelofibrosis, a life-threatening scarring of the bone marrow, leaves its victims weak and tired, with spleens uncomfortably enlarged as the disease advances toward leukemia. In the safety study, the spleens of all patients reduced in size by half or more. In half of the patients, spleen size returned to normal. Abnormal production of white blood cells ceased in all patients.

"It's exciting and kind of unexpected," Jamieson said. "This was supposed to be a safety trial."

The drug inhibited the stem cell's initial error, the mutation of a gene called JAK-2, named for Janus kinase 2. The gene mutates in 97 percent of all cases of polycythemia vera, in which the body makes too many red cells, half of all instances of thrombocytosis, in which there are too many platelets, and half of all cases of myelofibrosis. In the trial, half of all patients saw levels of mutant protein drop markedly.

"I thought it would be too little too late," Jamieson said. "I didn't think the results would be so good."

WHAT IS IT LIKE TO LIVE WITH LEUKEMIA?

In October 2008 Theresa Blanda was at a turning point.

Already she ached. A tumor grew on her knee, forcing her to use a walker. Now laboratory tests showed the blood disorder she had fought for five years was turning into leukemia. • Blanda had been diagnosed with polycythemia vera — an overproduction of red blood cells. But in 10 to 15 percent of all cases, the disease toggles into an overproduction of white cells and eventually acute leukemia. Blanda's body produced as many as 95,000 white cells per cubic millimeter of blood, far above the normal 8,000 or so. • "I was headed down the leukemic path," she said. • Her only hope was a bone marrow transplant, but there was no suitable donor. Then she learned of an experimental trial at the University of California, San Diego, targeting the stem cells that cause cancer. In October, she enrolled in the trial. • "Within two months I went from using a walker, to a cane, to walking on my own," she said. Her white blood cell count dropped to normal. • "They're hoping that treating this at the stem cell level means this can be treated like a chronic disease, like diabetes," Blanda said. "Will it keep working for me? I hope so."


"Within two months I went from using a walker,
to a cane, to walking on my own."
THERESA BLANDA

"The research is the most wonderful thing in the world. It's going to be the answer to so many things."
SHARON HAYES

Every day the cells essential for vision,
called photoreceptors, shed their outer layer.
And every day, a layer of cells just
below these photoreceptor cells consumes the discarded shells.
But in MACULAR DEGENERATION,
a sinister cycle emerges.

WITH AGE, THE CELLS BELOW THE PHOTORECEPTORS, CALLED THE RETINAL PIGMENT EPITHELIUM, lose cleaning efficiency, and in some 2 million Americans with macular degeneration, the loss is disruptive.

As the retinal pigment epithelium cells fall behind in house cleaning, toxins from the discarded shells build. The accumulation further damages the epithelial cells. Eventually, sections of epithelia die. Without the support of these cells, the photoreceptor cells necessary for vision die, too. Vision blurs at the very center of the eye. Over time, these blurry patches expand.

That's how dry macular degeneration takes eyesight, leaving the patient with an expanding blank spot in the center of his vision. This often turns into "wet" macular degeneration, in which leaky blood vessels quickly destroy sight.

Unlike wet macular degeneration, "Dry macular degeneration has no effective therapy," says Dr. David Hinton, M.D., a professor of pathology, neurosurgery and ophthalmology at the University of Southern California Keck School of Medicine. "That's where we're putting our efforts."

To attack the problem, Hinton grows sheets of retinal pigment epithelium cells derived from human embryonic stem cells. The hope is that these sheets can be used to rescue the photoreceptor cells losing their natural RPE.

So far, the lab-grown RPE layers function very similarly to natural cells. "There's evidence that what looks like RPE cells are RPE cells," Hinton said. In multiple tests, the lab-grown layers of epithelia secrete the same growth factors, provide the same nourishment and disposal processes, and express the same genes.

"They're not 100 percent identical, but they're very similar to normal RPE," he said.

Dr. Mark Humayun, M.D., Ph.D., has worked out how to get the new cells into the eye. The professor of ophthalmology, biomedical engineering, and cell and neurobiology at USC recently received a CIRM disease team award to pursue this work and is preparing for animal trials to test the concept.

"The cells are growing well in culture and exhibit most, if not all, of the important characteristics of normal RPE," he said. "So we remain very optimistic." If animal trials succeed, he hopes to see the procedure tried in humans in a few years.

WHAT IS IT LIKE TO LIVE WITH MACULAR DEGENERATION?

The images on the playing cards wouldn't come into focus, but Sharon Hayes kept trying to play bridge, making bidding mistakes as the game went along.

Finally, another bridge player had enough. "She said, 'Sharon, you've got to go to the doctor right now.' And we literally put down the cards and we went," Hayes said. • That's how the Pasadena-area woman learned she had wet macular degeneration in her left eye. But her eye had deteriorated beyond treatment. Leaky blood vessels growing beneath the retina left her with a gray cloud where people's faces should be — at the very center of her vision. • Her other eye had the dry form of the disease. It advances more slowly, but is untreatable. When it converted to the wet form, her doctor injected it with a drug called Avastin, which stopped the vessel growth. Within five days, the sight in her right eye was 20/25 again, allowing her to continue painting and running her landscaping business. • She puts her hope in studies to find new and better treatments. • "The research is the most wonderful thing in the world. It's going to be the answer to so many things," she said. "If something new came out, I would try it in a heartbeat."

The mice were old.

At 18 months, they were near the end

of their normal lifespan. Worse, the plaques and

tangles that signal

ALZHEIMER'S DISEASE ravaged their brains.

UNSURPRISINGLY, THEIR MEMORIES WERE WORTHLESS. They could be shown the safe harbor in a water maze — a test of mouse memory — every day and never remember where it was.

Frank LaFerla, Ph.D., director of the Institute for Brain Memory Impairments and Neurological Disorders at the University of California, Irvine, didn't believe stem cells held promise for Alzheimer's patients. But he let experiment decide the question.

LaFerla and his team injected neural stem cells into the hippocampus of the doddering mice. A month later, he put the mice into the water maze where they'd failed so miserably before. This time, the animals learned. They remembered. They performed every bit as well as their Alzheimer's-free peers. But it was puzzling. When LaFerla looked at the brains of the stem-cell treated mice, the diagnostic markers for Alzheimer's disease — amyloid plaques and neurofibrillary tangles — were still there.

"We found absolutely no difference," LaFerla said. "This is unparalleled. This is the first time in our lab — or probably any lab — we've been able to improve Alzheimer's without lowering plaque pathology. Likewise, we had no effect on tangle pathology."

Adding to the puzzle, few of the new cells turned into neurons. But when LaFerla looked more closely, he found the brain's learning center, the hippocampus, had new wiring — a dramatic increase in new connections between neurons, called synapses. The remaining neurons were branching and touching and talking to a greater number of other neurons than they had before the stem cells were injected.

"That was very interesting because the best correlate of cognitive decline is not plaques or tangles, but the degree of synaptic loss," LaFerla said.

Further studies revealed that the stem cells kicked off this communications revolution by secreting something called brain-derived neurotrophic factor, or BDNF. The stem cells also induced all the surrounding brain cells to squirt more BDNF.

In fact, the researchers were able to inject BDNF into mouse brains and induce synaptogenesis, but at half the level induced by stem cells. This suggests that secreting BDNF is only part of what stem cells do, LaFerla said.

"We got into this not expecting it to work," he said. "Now we know stem cells don't need to replace neurons. By implanting stem cells into brains, there is almost a doubling of synaptic density."

WHAT IS IT LIKE TO LIVE WITH ALZHEIMER'S DISEASE?

Dick Mora knew something was happening, but he didn't want to think about it.

Whole conversations would vanish from memory as though they never took place. It was frightening. • "We'd gone through quite a bit with my mother who had Alzheimer's disease," he said. "She wouldn't know who I was. So when things started happening to me, I was very, very nervous. I really kind of kept it to myself." • When he was finally diagnosed with Alzheimer's in 2003, the Laguna Niguel man thought it was the beginning of his personal fade to black. "I really believed I was going to be going down like Mother, that I wouldn't know my children, and I wouldn't know my wife." • But Mora, who retired from the pharmaceutical industry, was lucky. His doctor told him about an off-label use of an existing drug to stop the progression of Alzheimer's disease. Now, five years after his diagnosis — an amount of time normally marked by steep cognitive decline — Mora's disease has barely progressed. • "He can still drive a car," said his wife Nancy. "He is very self-sufficient." • "Without aggressive treatment, my life would have been much different," Mora said. "That's why I'm a very strong supporter of research and anything that could bring about a cure for this cruel and unforgiving illness."

"Without aggressive treatment, my life would have been much different."

DICK MORA

"I'm frustrated
when I can't button certain things,
when I can't zip things,
when I can't dance like I used to be able to dance."

BARBARA D'AMICO

They're like biological M&Ms — only very, very small ones — designed to treat ARTHRITIS. A shell of juvenile cartilage cells wrap a center formed of stem cells plucked from bone marrow.

TOGETHER, THEY MAY HOLD A KEY TO REPAIRING THE EARLY DEGRADATIVE changes of arthritis, according to Jeffrey Lotz, Ph.D., director of the Orthopaedic Bioengineering Laboratory at the University of California, San Francisco.

Medicine has little to offer the 16 million Americans with osteoarthritis beyond pain treatment and joint replacement. When a combination of genetic propensity and injury to cartilage kicks off the changes that lead to arthritis, there is no way to halt it. Arthritis can also be triggered by joint infection, aging or gout.

It's not a simple problem, Lotz said. Lack of adequate cartilage stem cells led Lotz to turn to the undifferentiated mesenchymal stem cells found in bone marrow. Then the question became how to make these cells — which can turn into fat, bone, cartilage or skin — into cartilage. Thus the M&M idea arose. The sheath of juvenile chondrocytes — cartilage cells — act like guides, sending signals that tell the stem cells, Hey, we're supposed to become cartilage.

The pellets are mixed in a biomaterial, like M&Ms in Jell-O, Lotz said, and put into damaged cartilage, where they grow into new tissue.

In tissue culture and tests in rabbits, the cells functioned according to plan. Whether they will work to replace native cartilage in weight-bearing joints awaits testing in larger animals.

William Robinson, M.D., Ph.D., assistant professor of immunology and rheumatology at Stanford University, looks at the other side of the arthritis problem.

"You have to treat the underlying pathogenic process to have successful stem cell therapy," Robinson said. "If the inflammatory process in the joint isn't attenuated, it doesn't matter what else you do."

By comparing gene expression patterns in synovial fluid from around the knees of people with and without arthritis, he confirmed that arthritis sufferers have a higher level of complement effector proteins. Complement proteins are part of the body's immune defense. When activated by antibodies, they destroy invaders. But in arthritis, they attack chondrocytes.

In animal studies, Robinson found that joint damage routinely turned into severe osteoarthritis in normal mice. But mice deficient in complement healed without arthritis.

"Inflammation and complement are playing a prominent role in degenerative arthritis," Robinson said. "If you want to be successful, in terms of slowing its progression and regenerating tissue, you're going to need to control that."

WHAT IS IT LIKE TO LIVE WITH ARTHRITIS?

Six days a week, Barbara D'Amico hits the gym.

"I do intensive workouts. I do weights. I do aerobics. That's my part-time job, to stay healthy," D'Amico said. • She's fighting rheumatoid arthritis. The Redwood City accountant has had the degenerative disease more than 40 years. She can make it seem like a snap; it's anything but. • "There are challenges every day — getting up, starting my day. I'm frustrated when I can't button certain things, when I can't zip things, when I can't dance like I used to be able to dance. But I still do my aerobics. I push myself. I challenge myself." • Today, the drug Orencia holds her disease at bay. "It's the best medicine I've ever had," she said. But when she was first diagnosed, doctors had little to offer. They told her to take it easy. • "I really didn't listen to the doctor. It's probably the best thing I ever did." • Seeing the way therapies have improved makes her hopeful for a future stem cell-derived treatment to restore the damage done by arthritis. • "I think in the long run it will help people and correct the deformity of the disease," she said. "The problem is, now, they can't reverse it."

Calling California

In 2009 the people of California had several opportunities to learn about the work of CIRM and the state of stem cell science. In the spring, CIRM-funded scientists spoke at in three town forums—in San Francisco, Los Angeles and San Diego. Each featured an overview of the field: scientists also gave talks on the basic questions in stem cell biology and on a therapy that is nearing the clinic.

Altogether, the town hall forums brought about 600 people up to speed on stem cell science in California.

While the town hall sessions reached out to adults, Stem Cell Awareness Day, held Sept. 23, engaged the next generation. Nearly 5,000 high school students saw presentations in biology class or in schoolwide assemblies held by CIRM scientists.

The day also included a poetry contest, won by high school student Jonathan Lee of the Drew School in San Francisco (short form) and Jessica Grubaugh of Purdue University (long form).

In recognition of the promise of stem cell research, the governors of California, New York and Wisconsin all proclaimed Stem Cell Awareness Days in their state, as did mayors of six California cities.

Worldwide, Stem Cell Awareness Day events included the launching of the Stem Cell Charter in Canada and a symposium at Monash University in Victoria, Australia.

Engaging the Nation

CIRM's reach goes well beyond stem cell science in California. Advancing the entire field means working at the national level to ensure that California scientists work in a regulatory environment that encourages stem cell research.

CIRM is working with the Food and Drug Administration to streamline the process of getting new stem cell therapies through the FDA and into the clinic. By bringing our grantees and the FDA into conversation now, those scientists will have a better idea of what they will need to present the FDA in order to be allowed to test prospective therapies in patients.

CIRM also had an influential role in responding to an initial draft of the new NIH guidelines for funding embryonic stem cell research. Working with CIRM grantees who are developing new embryonic stem cell lines, CIRM is ensuring that our grantees' lines make it into the national registry and are permitted in federally funded research.

Stem Cells, Oh Stem Cells,
Endless potentials have you.
The ability to grow and divide,
Self-replicate, reproduce and renew.
    Your diversity allows
For any kind of tissue.
To exist and propagate
Without many an issue.
    Your powers of healing,
And of critical repair
Enable our lovers
To never despair.
    Then why is it, Oh Stem Cell
That many assume
You've spawned from a corpse
Of an 'evil' one's womb?
    Where is the common notion
That the public should possess
That you've likely come from
A clinic, a cord or another address?
    Prejudged and discriminated,
You are misunderstood.
But you dominate survival
In ways others never could.
    You've shown the whole world
With genetic programming tech
That differentiation without limit
Should inspire Obama's next check.
    Your struggle, strong Stem Cell
Has influenced me
To live my whole life
With constant potency!

JESSICA GRUBAUGH, PURDUE UNIVERSITY
Poetry contest winner–long form

'TIS THE DAY TO PRAISE,
THE BASE OF LIFE UNHAZED.
THE WORLD IN ONE CELL.

JONATHAN LEE, THE DREW SCHOOL
Poetry contest winner – short form

Going Global Online

You don't have to be in California to learn about CIRM-funded research. People from around the world have read about stem cell research and browsed through our funded grants on our newly updated web page. With about 350 unique visitors per day, the site provides background information on the science, features about new developments and a comprehensive list of CIRM funding, in addition to materials from Governing Board meetings and funding opportunities.

CIRM offers several ways for people stay up to speed on our work. Videos on Youtube (www.youtube.com/cirmtv) explain advances in the field; images on our Flickr photo stream (www.flickr.com/photos/cirm) show the beauty of stem cell science; our blog (CIRMResearch.blogspot.com) provides ongoing updates of scientific progress; and Facebook fans receive frequent updates about our activities.

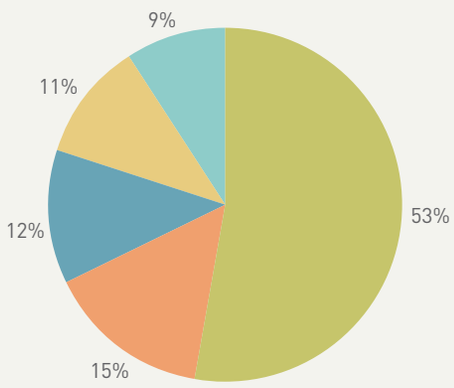
Taken together, our web content, videos and blog updates have been viewed more than 240,000 times this year. Most of those visits came from people in the United States, but we've also reached people in Canada, the United Kingdom, Australia, India, Japan, Germany, China and Spain, among others.

SCIENCE CATEGORY

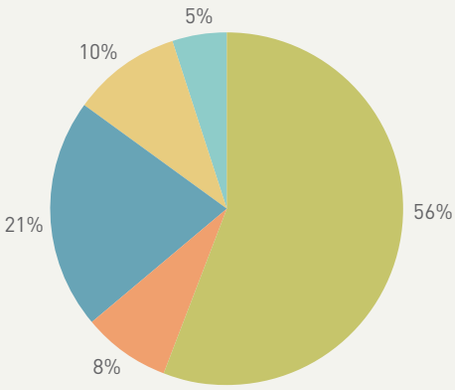
By award number

- FACILITIES
- TRAINING
- BASIC RESEARCH
- TRANSLATIONAL RESEARCH
- PRE-CLINICAL RESEARCH

Awarded grants



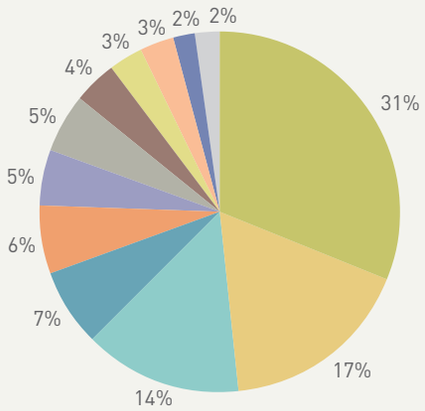
Applications



DISEASE CATEGORIES

By award number

- NEUROLOGICAL DISORDERS
- CANCER
- HEART DISEASE
- BLOOD/IMMUNE DISORDERS
- SENSORY ORGANS
- MULTIPLE DISORDERS
- OTHER DISORDERS
- MUSCULAR DISORDERS
- GASTRO-INTESTINAL DISEASE
- DIABETES
- BONE/CARTILAGE DISORDERS
- FERTILITY



DURING 2009 THE CIRM GOVERNING BOARD approved 75 grants that will pay out $338 million during the duration of the funded projects. That brings total grants awarded by CIRM through 2009 to 328—totaling more than $1 billion.

For a full report on CIRM finances visit the annual report online at www.cirm.ca.gov/2009AnnualReport

The Governing Board of CIRM

REPRESENTING PATIENTS, RESEARCHERS, BIOTECHNOLOGY – AND YOU

CIRM is governed by 29 dedicated Californians representing patients, researchers and the biotechnology industry whose knowledge, passion and commitment to CIRM's mission has guided the organization through a successful first five years. These board members serve on eleven subcommittees and on the three working groups that provide recommendations to the board regarding CIRM funding, ethical standards and facilities.

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Parkinson's Disease
Founder, Parkinson's Action Network

CIRM PUBLIC MEETINGS:

ICOC meetings: **54**

Subcommittee meetings: **93**

Standards working group meetings: **17**

Grants working group meetings: **19**

Facilities working group meetings: **15**

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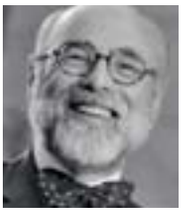

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MS/ALS

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YAIR REISNER, PH.D.
Weizmann Institute of Science

CAMILLO RICORDI, M.D.
University of Miami

GAIL ROBERTSON, PH.D.
University of Wisconsin-Madison

Total grants approved for funding

Institution	Total Grants	Total Funds
STANFORD UNIVERSITY	42	$162,979,744
UNIVERSITY OF CALIFORNIA, LOS ANGELES	32	$117,204,702
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO	30	$102,971,301
UNIVERSITY OF SOUTHERN CALIFORNIA	19	$71,128,925
UNIVERSITY OF CALIFORNIA, SAN DIEGO	25	$65,583,177
UNIVERSITY OF CALIFORNIA, IRVINE	22	$59,757,564
UNIVERSITY OF CALIFORNIA, DAVIS	15	$49,088,145
SANFORD CONSORTIUM FOR REGENERATIVE MEDICINE	1	$43,000,000
CITY OF HOPE NATIONAL MEDICAL CENTER	7	$36,730,319
THE SALK INSTITUTE FOR BIOLOGICAL STUDIES	13	$35,051,452
UNIVERSITY OF CALIFORNIA, BERKELEY	10	$34,626,605
SCRIPPS RESEARCH INSTITUTE	11	$27,560,249
BUCK INSTITUTE FOR AGE RESEARCH	5	$27,000,593
NOVOCELL, INC.	4	$26,281,356
SANFORD-BURNHAM MEDICAL RESEARCH INSTITUTE	15	$23,134,219
THE J. DAVID GLADSTONE INSTITUTES	13	$22,633,003
UNIVERSITY OF CALIFORNIA, SANTA CRUZ	9	$19,383,633
CHILDRENS HOSPITAL LOS ANGELES	7	$14,219,310
UNIVERSITY OF CALIFORNIA, MERCED	5	$8,494,301
UNIVERSITY OF CALIFORNIA, SANTA BARBARA	5	$8,490,842
UNIVERSITY OF CALIFORNIA, RIVERSIDE	4	$6,055,762
CEDARS-SINAI MEDICAL CENTER	2	$5,607,118
BIOTIME, INC.	1	$4,721,706
THE JACKSON LABORATORY WEST	1	$3,841,240
THE PARKINSON'S INSTITUTE	1	$3,701,766
SAN DIEGO STATE UNIVERSITY	2	$3,464,360
SCRIPPS HEALTH	1	$3,118,431
LUDWIG INSTITUTE FOR CANCER RESEARCH	3	$2,473,053
CALIFORNIA INSTITUTE OF TECHNOLOGY	1	$2,071,823
SAN JOSE STATE UNIVERSITY	1	$1,756,260
CALIFORNIA STATE UNIVERSITY, CHANNEL ISLANDS	1	$1,755,906
CALIFORNIA STATE UNIVERSITY, SAN MARCOS	1	$1,754,664
PASADENA CITY COLLEGE	1	$1,750,491
SAN FRANCISCO STATE UNIVERSITY	1	$1,736,058
CALIFORNIA STATE UNIVERSITY, NORTHRIDGE	1	$1,627,220
HUMBOLDT STATE UNIVERSITY	1	$1,638,863
CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA	1	$1,459,297
CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO	1	$1,419,009
CALIFORNIA STATE UNIVERSITY, LONG BEACH	1	$1,355,700
CALIFORNIA STATE UNIVERSITY, SACRAMENTO	1	$1,343,940
CALIFORNIA STATE UNIVERSITY, FULLERTON	1	$1,281,180
CALIFORNIA STATE UNIVERSITY, SAN BERNARDINO	1	$1,164,017
CITY COLLEGE OF SAN FRANCISCO	1	$1,110,608
BERKELEY CITY COLLEGE	1	$1,093,569
VISTAGEN THERAPEUTICS, INC.	1	$971,558
GAMMA MEDICA-IDEAS, INC.	1	$949,748
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"The Disease Team Awards are going to be beyond an experiment. This is going to be a 48 month sprint to success for all of those patients."

SENATOR DEAN FLOREZ

Heart muscle precursors derived from embryonic stem cells

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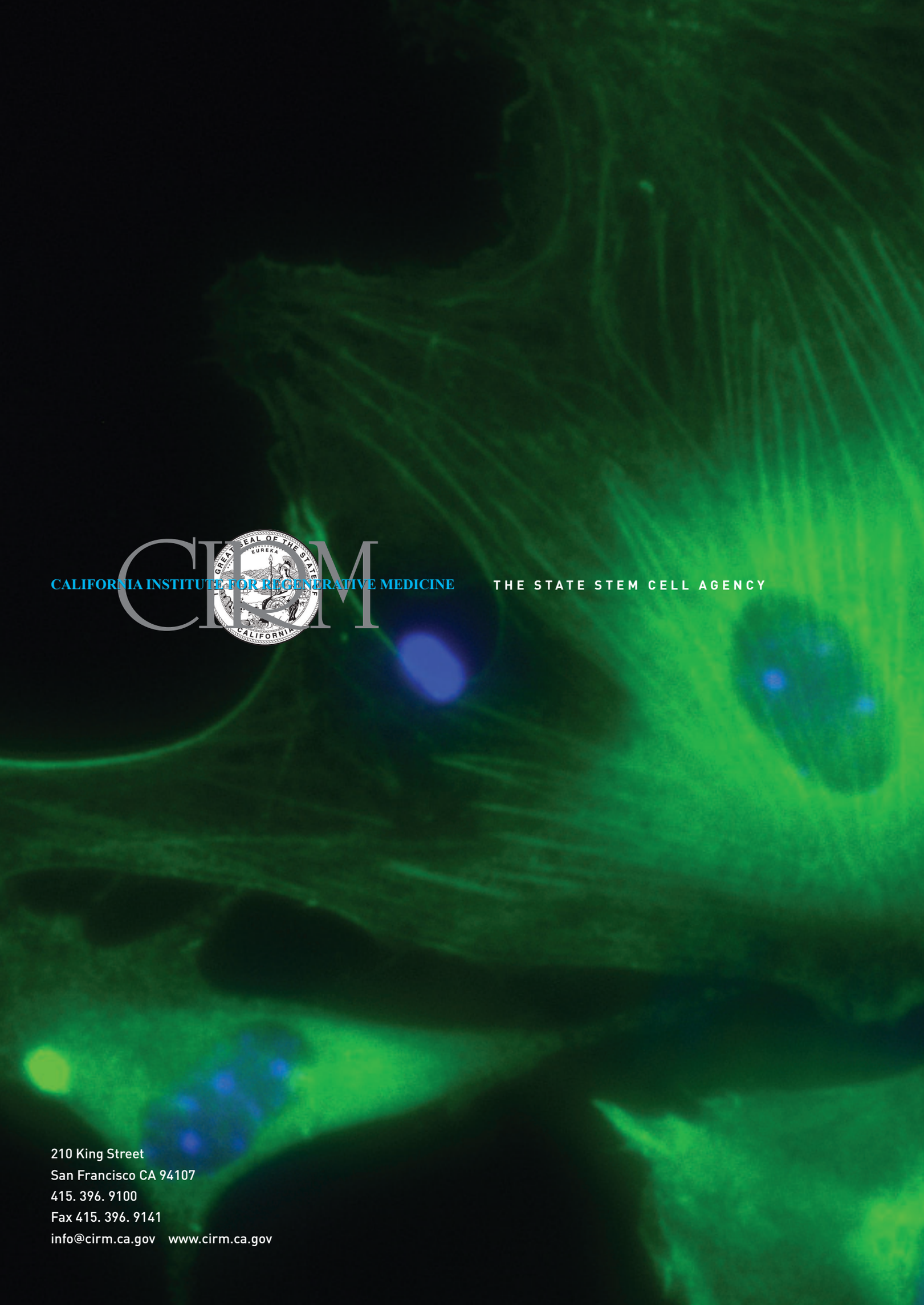

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