

Stem Cell Research

Status

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Prerequisites

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Executive summary and recommendations

Overview of this document

This document arises from the contributions of specialists in various areas of stem cell research, biomedical application and patient advocacy, who – in addition to writing the articles herein – were invited to a consultative meeting held under the auspices of EMBO on 19 April 2006. This summary document provides an introduction to the field of stem cell biology and its terminology for non-specialists and sets current research in the context of scientific knowledge production, relevance to major non-infectious diseases, and economic value. Furthermore, it gives recommendations addressing the policies needed in order to enable stem cell research to achieve its proper potential in Europe.

The areas covered are:

Themes and techniques

- The nature of stem cells and their differentiation into specific cell types
- Embryonic stem cells: potency and potential
- Somatic cell nuclear transfer (SCNT) in the production of embryonic stem cells

Tissue-specific research

- Blood
- Bone
- Cancer (stem cell model)
- Cardiac muscle
- Endothelia
(lining of vessels of the circulatory system)
- Epithelia (skin and other external surfaces)
- Brain and nervous system
- Pancreas
- Skeletal muscle

From theory to therapy

- Evaluating the therapeutic potential of stem cells
- Commercial development of embryonic stem cells: report from a company operating in the USA
- Perspective of an international patient advocacy organisation

Current status

Several applications of stem cells in tried and validated therapies are recognised in humans: from bone marrow transplants through to more recent advances in skin and cornea repair. The cells used in these cases are adult tissue stem cells whose normal function is to maintain and repair tissues throughout life. Stem cells are known to exist in several adult tissues, but they are usually rare. Their exact role, frequency of occurrence, and identity are generally not well understood.

Parallel research on stem cells derived from the earliest stages of embryonic development, has defined a primordial progenitor cell that is capable of producing all tissue types of the adult (pluripotent). Embryonic stem cells (ES cells) are remarkably potent on the one hand, and on the other they are difficult to control at the present state of knowledge.

Because adult tissue stem cells are restricted in the range of cell types they can make, there is great interest in the possibility of converting adult cells into pluripotent stem cells. This could be achieved either *via* the technique of somatic cell nuclear transfer (SCNT) – as used to create Dolly the sheep – or by other methods. Such research is still in its infancy, but it may offer

Adult stem cells are currently used in a number of therapies in humans, but they are rare and not yet well defined...

Embryonic stem cells can reproduce all tissues of the adult, but are currently hard to control...

Researchers are working on making similarly potent cells from adult cells...

The combination of studies on adult and embryonic stem cells is advancing biomedicine...

However, there is little interest from industry in Europe because of the current patent situation...

Stem cell research is beginning to address many important diseases, and some new therapies will move from pre-clinical to clinical trials soon...

Diabetes, atherosclerosis and leukaemia treatment are likely to benefit from such research...

ES cells show great potential in treating degenerative diseases and as pharmaceutical testing platforms...

Found in a growing number of tissues, adult stem cells could be amenable to activation by drugs etc. to carry out innate tissue repair...

Because adult stem cells do not appear to have much capacity for diversifying, researchers are working on "reprogramming" the nucleus to a more primordial state; this has potential for treating serious hereditary diseases...

Stem cell technology will continue to move apace in the USA with the involvement of industry...

great possibilities for regenerative medicine in the future.

Research on both ES cells and adult stem cells is advancing our knowledge of the biology of stem cells in general, as well as providing prospects of therapies for a variety of tissue-specific diseases, including such major illnesses as type 1 diabetes and Parkinson's disease. Research is also increasing our understanding of the biology of cancer, which may arise through mutation of stem cells.

Currently there is relatively little commercial support for, or industry engagement in, stem cell research and development in Europe. A significant inhibitory factor is the European Patent Office's interpretation of the morality clause in the European Biotechnology Directive (adopted into the European Patent Convention), which relates to the patentability of inventions dependent – at some point in their development – on the use of the human embryo. This is recognised as a serious impediment to obtaining full benefit from stem cell research and development.

Prospects

Stem cell research is at the beginning of a development that will likely address many important diseases for society, particularly in the ageing population. Stem cells do not only offer the hope of reconstructive therapies: A better understanding of their biology and the markers that distinguish them from "normal" cells, will likely contribute to better prognosis and finely targeted drug treatment of cancers.

Some potential stem cell therapies are already in pre-clinical tests in animals. In the skin and blood systems stem cell research is already moving into a second phase, in which gene correction in combination with cell therapy is used to target serious heritable diseases. In the coming 2-5 years, more stem cell based therapies are planned to enter clinical trials, notably in the areas of muscle regeneration and bone injury.

In the search for a cure for type 1 diabetes, much attention is now focussed on stem cell sources – embryonic, foetal or adult – that may be used to renew the insulin-producing beta cells that are destroyed in this chronic debilitating disease. In atherosclerosis research, findings on circulating endothelial progenitor cells (cells that form the lining of blood vessels) may contribute to improved prognostic indicators and new

therapeutic strategies. In the blood system there is scope to improve bone marrow and umbilical cord blood transplants. This research will also lead to a better understanding of leukaemia cancer cells, and through that to more accurately targeted drug therapy.

ES cells may ultimately be invaluable in a variety of tissue regeneration scenarios. Trials in rat models of Parkinson's disease already demonstrate the potential of cell replacement in the nervous system. Furthermore, the proliferative potential of ES cells creates the basis for an endless supply of human cells for modelling cellular development and disease, and for pharmaceutical testing. Research on adult and ES cells are interlinked, and will increasingly be mutually beneficial as better expansion and directed differentiation of ES cells are achieved.

As far as adult stem cells are concerned, research also aims to identify and characterise resident stem cells in a growing number of tissues. A better understanding of their normal mechanisms of activation in tissue damage repair will likely open the way to directed control of this innate repair machinery by pharmaceuticals, cytokines and growth factors. There are hints of such developments already in research on brain and neural tissues as well as heart – ultimately it could apply wherever tissue-specific stem cells exist in the adult.

However, there is currently little evidence for the persistence of pluripotent cells in adult tissues. Therefore a major goal of stem cell research is to find ways of "reprogramming" adult cells to a pluripotent state. SCNT is one way of achieving this. The technique may soon be used to create ES cells from a patient for investigation of motor neuron disease (amyotrophic lateral sclerosis). Other serious hereditary degenerative diseases are amenable to this approach – in this context, the potential power is in understanding inherited cellular diseases for which the gene(s) has not yet been identified and/or there is no good model system available. Research into SCNT should also lead to an understanding of the mechanism of reprogramming and accelerate the development of methods that do not require nuclear transfer into enucleated eggs.

Industry increasingly has a crucial role to play in the development of stem cell technologies, and in the United States it is actively doing so in the areas of glial cells (support cells in the nervous system) for spinal cord injury, cardiomyo-

cytes (heart muscle cells) for heart disease, islet cells for diabetes, haematopoietic cells (cells that give rise to all blood cells) for blood diseases, and hepatocytes (liver cells) for pharmaceutical testing.

Concerns, problems and open questions

Although the development of stem cell applications is sometimes presented as involving a choice between ES cell research and adult tissue stem cell research, biomedical advances can be foreseen equally from both approaches. It is known that ES cells are pluripotent, having the capacity to generate any cell type in the body. However, that potency is offset by some lack of certainty as to their stability in a partially or completely differentiated state, and a limited knowledge of the signals that are necessary to achieve definitive differentiation. Adult stem cells, while restricted in the range of cell types that they can generate, are more amenable to controlled differentiation, precisely because they have fewer choices available. However, what can definitively be demonstrated is that research in each field benefits the other at the levels of basic science and application. It is, therefore, wise to support both.

The stem cell is an entity that should be understood and manipulated in the laboratory before reintroduction to the patient. In general, the direct regenerative effect of stem cells is due to the proliferation and differentiation of the cells in the desired tissue. In some cases, however, cell transplantation may have indirect beneficial effects due to anti-inflammatory and growth signals that the introduced cells emit – the so-called “bystander” effect. More tissue-based research is necessary in order to clarify exactly how introduced cells interact with the host tissue, and what the essence of their regenerative power is. On the basis of such research, optimised therapies can be developed. Some types of tissue regeneration likely require the introduction of two or more cell types in order to have optimal clinical benefit. In other cases it may be more effective to administer a mixture of cytokines rather than, or in addition to, introducing cells.

In principle a genetic defect in the tissue to be treated may be repaired using stem cells. Using a patient’s own cells and repairing/replacing the gene in question avoids the problems of immune

rejection of foreign cells. This could provide a longer-term therapy, or even cure. The value of such “genetically corrected” stem cells has been demonstrated at the level of proof of principle. However, it may require the development of alternative methods to the hitherto used viral vectors in order to be accepted for widespread clinical application.

In certain applications (i.e. skeletal muscle and the lining of blood vessels) infusion of stem cells into the circulatory system can be used as the route of administration. However, in the majority of applications of cell-based therapy, introduction of cells directly to the site of repair/regeneration is likely to be necessary. This will require techniques and equipment specifically tailored to each clinical application, and the application of sophisticated imaging technologies to track the introduced cells. Furthermore, several experimental approaches – notably in bone and cartilage repair – rely on the development of suitable “scaffold” materials on which cells can grow prior to implantation. Research on such bio-compatible materials must keep pace with stem cell research, and production must be scaled up to satisfy demand.

In both basic and clinical stem cell research, progress is required in selecting from a tissue only the rare population of true stem cells among a mixture of partially differentiated progenitor cells. Such cell sorting is important in order to increase the efficacy and specificity of the dose of cells finally administered. In many areas of research it remains to be seen whether progenitor cells grown in the laboratory are still capable of differentiating and functioning properly after transplantation. Clearly, consistency of production and quality control are prerequisites for safe clinical application of cell therapies. However, the efficacy of the cells designated for therapy is at least as important as their safety. Cells that appear to pass overly stringent regulatory control may do so at a price: they may lose a subtle component of their potency to regenerate tissue, and upon transplantation they may no longer behave as desired. It is therefore essential to maintain an appropriate perspective and avoid compromising the functionality of stem cells before transplantation. An important consideration is whether the current level of regulation – with the associated bureaucracy and costs – would have allowed the development of life saving stem cell therapies for

Adult and embryonic stem cells have different advantages and disadvantages; research on both is complementary and crucial...

For effective administration, stem cells must be well understood and specially prepared; further research is needed to clarify the role in tissue regeneration of the cells themselves and the chemicals they emit...

Genetically altered stem cells could be used to treat and correct genetic diseases, but this may require new methods for introducing the “repair” gene...

Most therapies will be given directly into the tissue in question, requiring sophisticated administration and imaging technology, and in some cases “scaffolds” of advanced materials to grow the cells...

Obtaining the right cells from a tissue, and ensuring that they remain effective until administration are crucial; efficacy controls are as important as safety controls, and must not be swamped by the latter...

Large investments would be necessary to scale up therapies for general availability; to minimise immune rejection, large numbers of cells would need to be banked; SCNT with patients' own cells needs to be researched further as a complementary strategy...

But legislative obstacles are hindering basic research...

And techniques and products involving the use of a human embryo remain unpatentable in Europe; researchers' main concerns are the techniques for manipulating stem cells and the differentiated cells that result...

The appeals process of the European Patent Office is dealing with the matter, but a resolution is not expected before 2008...

Meanwhile patents on human ES cells are granted elsewhere around the world...

Leaving Europe at a big disadvantage because the situation is so complex and far from positive resolution that there is little industry interest in ES cell R&D...

blood disorders in the 1960s and severe burns in the 1980s.

A further concern at the level of delivery of stem cell therapies is that very significant investments need to be made if such therapies are to be generally available one day. Infrastructures for scale-up, safety and quality control, as well as distribution and storage need attention before therapies start to move out of clinical trials and become generally available therapies. Furthermore, should ES cells prove to be a therapeutic that is applicable to a large number of diseases, the problem of immunological rejection will need to be overcome. This may be tackled by banking a relatively large number of ES cell lines in stem cell banks for histocompatibility matching (as used in organ transplants), combined with immunosuppressive drugs or strategies to induce tolerance. The derivation of ES cells from a patient *via* SCNT or direct reprogramming represent alternative possibilities, but such techniques need to be firmly proven and then developed into an efficient process.

A major concern hanging over the field of stem cell research – more particularly research with human embryonic stem cells (hES cells) – is that there are legislative obstacles to free international collaboration and exchange of materials. The disparate national regulations governing stem cell research in Europe inhibit the field from benefiting from the internationality of approach inherent to scientific advance. In some countries scientists are allowed to pursue research with a limited number of human ES cells, but are faced with the threat of prosecution if they engage in research on other human ES cell lines developed by collaborators in Europe.

In the context of economic value and patents, European stem cell researchers are concerned with the protection of intellectual property relating to the manipulation of established human ES cells and differentiated derivatives, not to their derivation from the human embryo. However, the current stance of the European Patent Office (EPO) is to exclude from patentability all inventions or claims relating to human embryonic stem cells. This position has its roots in rule 23d(c) of the European Patent Convention (the legal framework in which the EPO operates), which stipulates that “European patents may not be granted in respect of biotechnological inventions which, in particular, concern uses of human embryos for industrial or commercial purposes.” According to current EPO interpretation, that

excludes from patentability all claims to associated products necessitating the direct and unavoidable use of a human embryo – including claims on cells derived from an embryo.

Whether this interpretation is correct, and in particular whether inventions using established hES cell lines – being procedurally distant from the original embryo – should be subject to patent exclusion, rests on the verdict of the EPO's enlarged board of appeal. That decision may well not be reached until some time in 2008. To the extent that the final interpretation of the European Patent Convention article 23d(c) might exclude from patentability all applications of, and techniques pertaining to, human ES cells, it would have a major negative impact on future commercial investment in this area in Europe.

This unusual situation – patents on human ES cells are granted elsewhere around the world, notably in the US – and the lack of a verdict at the EPO present the temptation for researchers or companies to apply for national patents in individual European countries instead. But – depending on the particular case and the interpretation of the European Biotechnology Directive – that process risks contravening the very instrument designed to aid harmonization across Europe (the Directive itself), hence potentially precipitating legal proceedings at the European Court of Justice.

In summary, the intellectual property situation is so complex, and so far from a positive resolution, that there is little – if any – incentive for commercial involvement in the development of ES cell applications in Europe. Since patents on human ES cells are already granted in the United States and elsewhere, investors and bioindustry are focussing on those opportunities. This situation renders the European biotechnology sector at a serious disadvantage compared with global competitors, and carries potentially damaging consequences for the economy and healthcare.

Recommendations

In order that stem cell research and development in Europe stand the maximum reasonable chance of fulfilling their potential for advancing health-care, the biological sciences and the economy...

- **1.** The prospective value of stem cell research in benefiting healthcare, knowledge production and the economy should be publicly recognised. Human stem cell research should be integrated into the mainstream of biomedical research, including disease modelling, study of cellular degenerative processes, development of pharmaceutical and toxicological screening platforms, and regenerative therapy.
- **2.** Research on both adult and embryonic stem cells, being highly complementary, should be fully supported; so too should research into understanding the reprogramming of the nucleus brought about by somatic cell nuclear transfer (SCNT), cell fusion and other techniques.
- **3.** Communication and professional education on stem cell research and applications should be promoted with active participation of scientists and clinicians along with ethicists, regulators and patient group representatives.
- **4.** Intellectual property relating to the utilisation of human ES cells and cell lines after their derivation from the embryo should be patentable in order to encourage the necessary industry involvement in the translation of stem cell research into clinical applications.
- **5.** Regulations relating to stem cell research and applications should be clarified and harmonised, and wherever possible legislative obstacles to free international collaboration between scientists removed.
- **6.** Care should be taken that regulatory requirements are not excessively stringent and do not present an unreasonable financial and/or bureaucratic barrier to clinical applications, as currently threatens.
- **7.** Efficacy measures and standard operating procedures for clinical use of stem cells should be developed. In establishing clinical practices, efficacy measures should be accorded at least as much significance as that of safety controls.
- **8.** Stem cell banks with high levels of quality assurance should be encouraged, and international access by scientists and industry facilitated.
- **9.** Greater harmonisation and interlinking of clinical trials and their results across Europe should be promoted in order to facilitate cross-border studies and evaluation of all cell therapies (including, but not limited to stem cell therapies). Such an initiative should be for the benefit of all citizens and underpinned by public funding.
- **10.** Investments should be made in technology development to enable large-scale processing of stem cells for applications in pharmaceutical screening, toxicological testing, and cell transplantation.

Introduction

Stem cell research is both an evolution and a revolution in modern biomedicine. It can be regarded as a milestone on a progression of signal findings and developments: from small molecule antimicrobials (e.g. penicillin), antibodies and monoclonal antibodies, to modern genetics, genomics and cell therapy. Indeed, it is possible only because of the multitude of discoveries in biology that precede it. At the same time, it is quite different from anything so far attempted in biomedicine on a global scale. Stem cells – particularly embryonic stem cells (ES cells) – represent part of the post-genomic technology for delivering on the promises of the human genome sequencing project. Commercial companies in the USA already use genomics to derive ES cell lines.

Despite its revolutionary nature, the concept of using stem cells for therapeutic purposes has much in common with the now conventional principle of organ transplantation; but rather than introducing a whole new organ to a patient, only a certain population of cells is given. Furthermore, if these cells are from the same individual, the problem of immune rejection is also avoided. Some established cell therapies relying on stem cells can even be regarded as intermediate between organ transplantation and cell therapy: for example, bone marrow transplants and transplantation of pancreatic islets (groups of so-called β -cells that produce insulin in the pancreas). Transplant technology has allowed medicine to heal people in ways unachievable by mere surgery or medication; the same can be said about the prospects of stem cell technology. Furthermore, stem cells have the potential to treat a broad spectrum of diseases from the common to the rare, and across all age groups (e.g. rheumatoid arthritis, Duchene muscular dystrophy and congenital immune deficiencies).

There are already well-validated clinical applications of stem cells. Thousands of patients have benefited from bone marrow transplants, for example. During the Cold War the fear of nuclear war prompted an acceleration in research to repair human tissues that are particularly prone to radiation damage (renewing tissues that replace themselves continuously throughout life) such as the blood. Experiments in mice showed that following destructive irradiation, the entire blood system could be regenerated *via* bone marrow cell transplantation. The first successful human bone marrow transplant resulting in the long-term survival of the patient (a leukemia sufferer, whose bone marrow had been destroyed by radiotherapy) was performed in 1956 by Dr. E. Donnall Thomas, New York; the proof of principle was turned into a life-saving clinical application. Further signal advances were made by other researchers in 1968 (first bone marrow transplant using a related donor for non-cancer treatment) and 1973 (first bone marrow transplant using an unrelated donor). Today many thousands of lives are also saved by stem cell skin grafts to burns victims, and many hundreds of eyes are saved from blindness with the help of corneal stem cells. In certain cases of corneal injury, traditional transplantation fails simply because the transplant does not regenerate itself as the normal tissue does. Stem cells can overcome this problem.

A significant number of diseases targeted by stem cell therapy are due to a faulty gene that manifests its effect in a particular tissue or sub-population of the patient's cells. Using genetically corrected stem cells to repair faulty genes in the patient appears an attractive alternative to the classical method using viral vectors to deliver the repair gene *in situ*. Genetically corrected stem cells are proving their value in clinical trials

Stem cell technology represents a revolutionary way of exploiting human genome data...

But it is also closely related in principle to well established and successful transplantation technology...

It has already proven itself in several clinical settings, and has the potential to address a broad variety of diseases...

Even to the extent of repairing the genetic defect that gives rise to certain diseases...

Stem cells may be derived from adult and foetal tissue, and from embryos...

But their characteristics can differ greatly depending on their source...

Adult stem cells cannot be considered a replacement for embryonic stem cells...

Pre-clinical testing in animals is crucial for the safety of stem cell-based therapies...

Cells will predominantly be administered directly to the site of repair...

And will most likely be at least partially differentiated beforehand...

Stem cell research also gives insights into intrinsic tissue repair mechanisms, disease processes and normal tissue function...

And could provide the basis for better pharmaceutical testing methods and ways of studying diseases, particularly rare ones...

for at least one seriously debilitating hereditary skin disorder.

Stem cells vary greatly in derivation, proliferative capacity and diversity of adult cell types to which they can give rise.

Stem cell sources:

- Adult stem cells obtained from so-called niches in adult tissue (such cells have been identified in many tissues from brain to muscle)
- Foetal stem cells (e.g. from aborted foetuses or umbilical cord blood)
- Embryonic stem cells:
 - From disused *in vitro* fertilisations
 - *Via* nuclear transfer (also known as “somatic cell nuclear transfer”), in which the nucleus from a normal body cell is placed into a fertilised egg from which the original nucleus has been removed. The environment of the fertilised egg has the effect of ‘re-setting’ the transferred nucleus to a kind of primordial state.

The notion that adult stem cells can replace embryonic stem cells – hence side-stepping the ethical concerns of the latter – is frequently cited. However, the potential of adult stem cells to solve problems should not be overstated, especially since (as is shown in box 1) the nature of adult stem cells from different tissues is not completely understood. Embryonic stem cell research contributes to the understanding of adult stem cell biology and *vice versa*. More research is urgently needed to move the field beyond the uncertain current position regarding the benefits and relative merits of different stem cell applications.

An inevitable and very important part of this research involves the use of animals. From the first experiments on bone marrow transplantation to current day genomics experiments (defining the genetic nature of stem cells and their development), animal experiments have been indispensable. Where therapeutic applications are concerned, no regulatory authority (neither the FDA nor the European EMEA) would consider an application that is not supported by pre-clinical safety and toxicity tests in animals.

In order for a stem cell therapy to enter the clinic, many challenges must be met. Several open questions surround the mode of delivery of the cells. The method, route and site of introduction to a patient are likely to be specific to the

particular stem cell and its purpose. The potential for local delivery to the tissue of interest has been markedly improved by developments in catheter technology, further improving safety. The concept of infusing cells into the blood and allowing them to reach the desired target is probably only of merit in a minority of cases (e.g. damage to the blood vessel lining or other directly accessible parts of the vascular system).

In clinical application, stem cells will most likely be at least partially differentiated before introduction to the patient. The introduction of undifferentiated stem cells would at most be the rare exception. Pre-differentiated cells represent a more controlled material, which is already set on a path to becoming the desired tissue. However, for repair of external skin defects, *in vitro* generated epidermis containing undifferentiated adult stem cells is currently used with success.

Though stem cells are overwhelmingly thought of in terms of a material to be administered as a therapeutic, it is important to realise that they also allow researchers to understand the way in which resident stem cells can be mobilised to repair damage “from within”. Current work in the field of muscular dystrophy and muscular atrophy is such an example. Moreover, stem cells are an experimental resource in themselves, enabling researchers to better understand cancer, developmental biology, pharmacology, degenerative diseases and the maintenance of normal physiological function, to mention a few topics.

Stem cells – because they can be differentiated into a variety of cell types found in our bodies – represent ideal material for the testing of pharmaceuticals: for therapeutic effects on specific cells, for unwanted side effects, and for breakdown by liver cells. In principle, stem cells derived from a person could provide an individual profile for response and toxicity of a given medicine. Such use of stem cells is estimated to be a huge area of application, with a significant impact on the safety of medicines. For studying how different tissues are affected by a particular disease, and in pharmaceutical testing, somatic cell nuclear transfer (SCNT) technology represents an attractive potential way of making the necessary stem cells. SCNT would in principle make possible the controlled production of genetically identical but functionally different cells from an individual. It would also offer an attractive way of studying orphan diseases, for which there are few sufferers and a low availability of clinical samples.

Embryonic stem cells	Adult stem cells
Are a ubiquitous component of the embryo, with a well-understood function and life history.	Are rare, often difficult to identify, of unknown origin, and partially understood function and life history.
Are defined by position in the embryo (the inner cell mass of the blastocyst).	Are defined by a complex list of features such as cell-surface markers, behaviour <i>in vitro</i> , and in some cases, position in the tissue.
Can divide symmetrically indefinitely in culture without changing characteristics.	Can divide few or many times (up to 200 or more) in culture, but not indefinitely.
A single cell can give rise to a colony of genetically identical cells with the same properties as the original cell.	In some tissues, absolutely consistent precursor cells can be identified and cultured; that remains to be shown for all tissues.
Pluripotent: can give rise to all three tissue types of the embryo (endoderm, mesoderm and ectoderm).	Sometimes multipotent: most only give rise to their tissue of origin, but some may be able to give rise to different cell types within the larger groupings of endoderm, mesoderm and ectoderm (so-called plasticity)

Box 1 Crude comparison between embryonic and adult stem cells

In conclusion, stem cells are an enormous – as yet partially tapped – resource of biological knowledge, and through this knowledge a major new hope for improved therapies. Stem cells have already proven their worth in treating certain diseases and types of tissue damage. They have benefited thousands of patients already, and offer tangible prospects of application in other diseases and clinical settings. Furthermore, research on stem cells leads to the accumulation

of crucially important information of relevance to fields of research as diverse as cancer and degenerative diseases. Indications from established clinical application, research and development are that the science and technology of stem cells have the potential to benefit medicine, industry and the larger economy in very significant ways – if correctly supported at the levels of funding and policy.