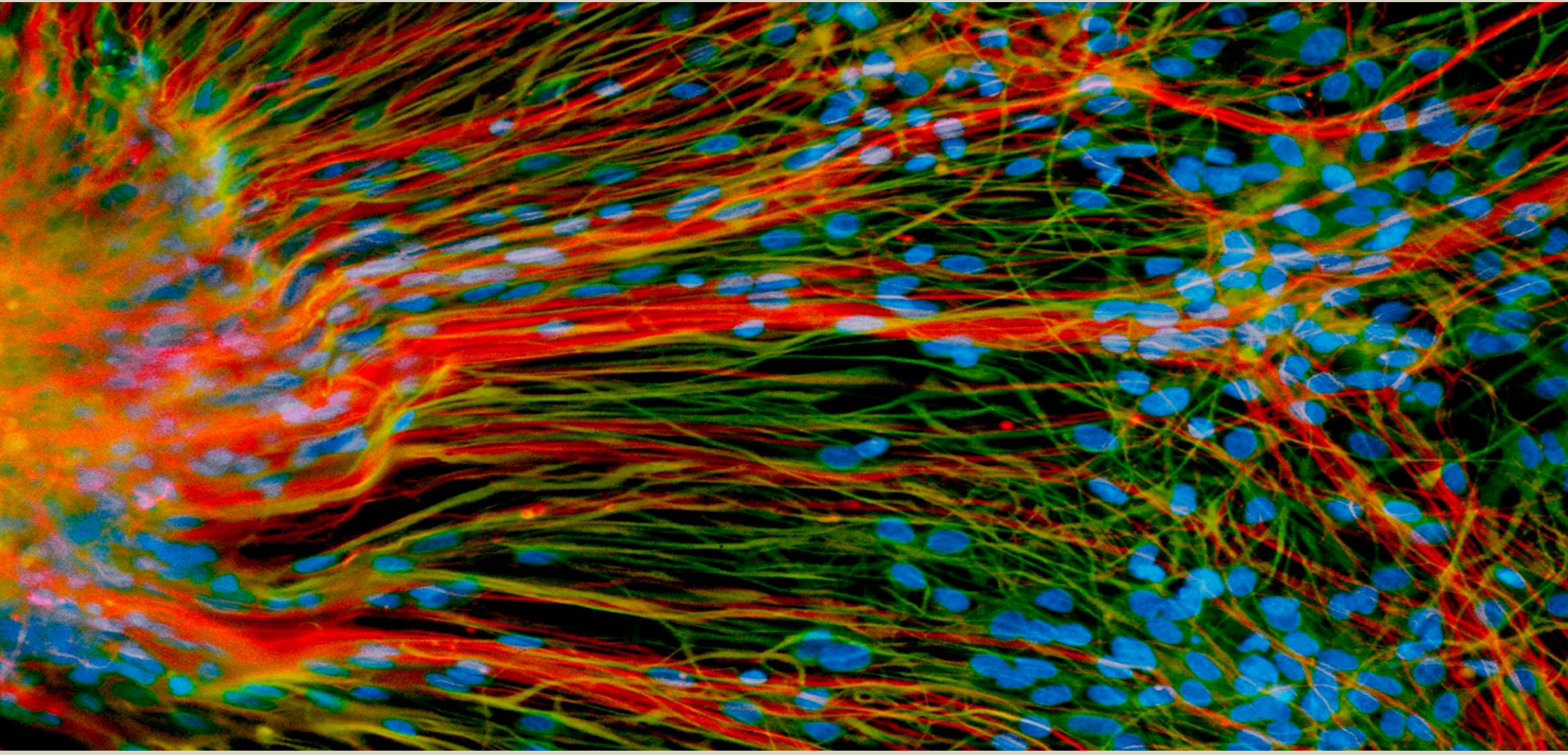
ADVISORY REPORT ON STEM CELLS: AGEING AND REGENERATIVE MEDICINE



AKADEMI SAINS MALAYSIA

UPM UNIVERSITI PUTRA MALAYSIA BERILMU BERBAKTI

ASM ADVISORY REPORT 4/2013

Advisory Report on Stem Cells Ageing and Regenerative Medicine

Academy of Sciences Malaysia

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Foreword

Over the last decade, stem cell research and therapy has attracted much attention from the scientific community and the lay public, both because of the extraordinary promise and the difficult ethical issues that accompany this field.

The potential of stem cell therapy and regenerative medicine to improve the health and function of our senior citizens is tremendous. This is especially important given that Malaysia's population is rapidly ageing and the cost of healthcare to both individuals and society will correspondingly increase.

Stem cell research locally is being carried out in the private and public sector across multiple institutions, and it is difficult to determine the current state of progress and research capacity nationally for this field. This is important as an objective assessment will enable the government to determine the priority for resource allocation based on the likelihood and magnitude of return on its investment.

As such, the Academy of Sciences has commissioned a Task Force to prepare an advisory report with the following terms of reference:

(a) To ascertain the current status of the ageing population in Malaysia and issues relevant to ageing.
(b) To ascertain the current state of art and capacity of stem cell treatment and therapy in Malaysia
(c) To identify the legal, ethical and religious framework already in place and the shortfalls, if any.
d) To ascertain whether the current policy and funding on stem cells and ageing research are adequate; and
e) To investigate whether there is a role for traditional and complementary medicine (TCM) in regenerative medicine and prevention of ageing.

The Task Force was headed by Emeritus Prof. Cheong Soon Keng, and comprised of subject matter experts from the research institutions active in stem cell research. Findings from the draft report were presented to various stakeholders in this field at a workshop, and the feedback was incorporated into the final report. The Institute of Gerontology at Universiti Putra Malaysia provided full access to its research database on the state of the ageing population and hosted the abovementioned workshop.

The publication of this Advisory Report is in fulfilment of one of the Academy's functions, namely to provide independent advice to the Government through dissemination of ideas and suggestions from scientists, engineers, and technologists through identifying where the innovative use of science, engineering, and technology can provide sound solutions to particular national problems.

I am glad that this Advisory Report will be disseminated and made available to the various relevant Ministries, universities, and research institutes for wider public consumption.

Tan Sri Dr Ahmad Tajuddin Ali, FASc
President, Academy of Sciences Malaysia

Preface

Malaysia is currently at a crossroad in its development in which important decisions must be made which will determine whether it is able to realise its ambition of becoming a developed nation by 2020. We have many advantages such as rich natural resources, favourable demographics, and a strong scientific tradition. However, the gulf between developing and developed nations is wide, and this can be bridged only by having a consistent policy of investment in both our infrastructure and human capital.

While funding for research is reasonable considering our current stage of development, there is a big shortfall in highly qualified manpower. Approximately ten percent of tertiary educated Malaysians have migrated to other countries, and the figure is worse for researchers, of which about one-third have gone abroad. Moreover, the total research expenditure for Malaysia is less than 1% of what the United States spends. If we want to survive as a small fish in a big pond, we need to think smart and consider solutions that are 'out of the box'. Our country does not have the resources to do everything, and we will need to pick and choose carefully to maximise the return on our research investment. We have to adopt a 'blue-ocean' strategy.

Life sciences and biotechnology is one of the cutting edge areas in which we should be focusing our attention. In this area, cell therapy is projected to become the key research field within the next five years. This advisory report aims to give an overview on the current state of cell therapy research in Malaysia, and provide policy recommendations which can help to steer its growth in a direction which contributes to our nation's development.

Prof Emeritus Dr Cheong Soon Keng, FASc
Chairperson,
ASM Task Force on Cell Therapy: Ageing and Regenerative Medicine

Contents

The population in Malaysia is ageing rapidly
This results in a smaller labour force supporting more dependents, thus limiting economic productivity
Disability levels are relatively high in Malaysia, which reduces the number of older people in the labour force, while increasing health and social costs for the nation
The top four chronic diseases which cause disability are dementia, musculoskeletal diseases, visual-hearing impairments, and cardiovascular diseases
Reduction of disability can extend the productive life of older people
Stem cell therapy can achieve this by regenerating damaged tissues and organs, thus restoring lost function

Population Ageing

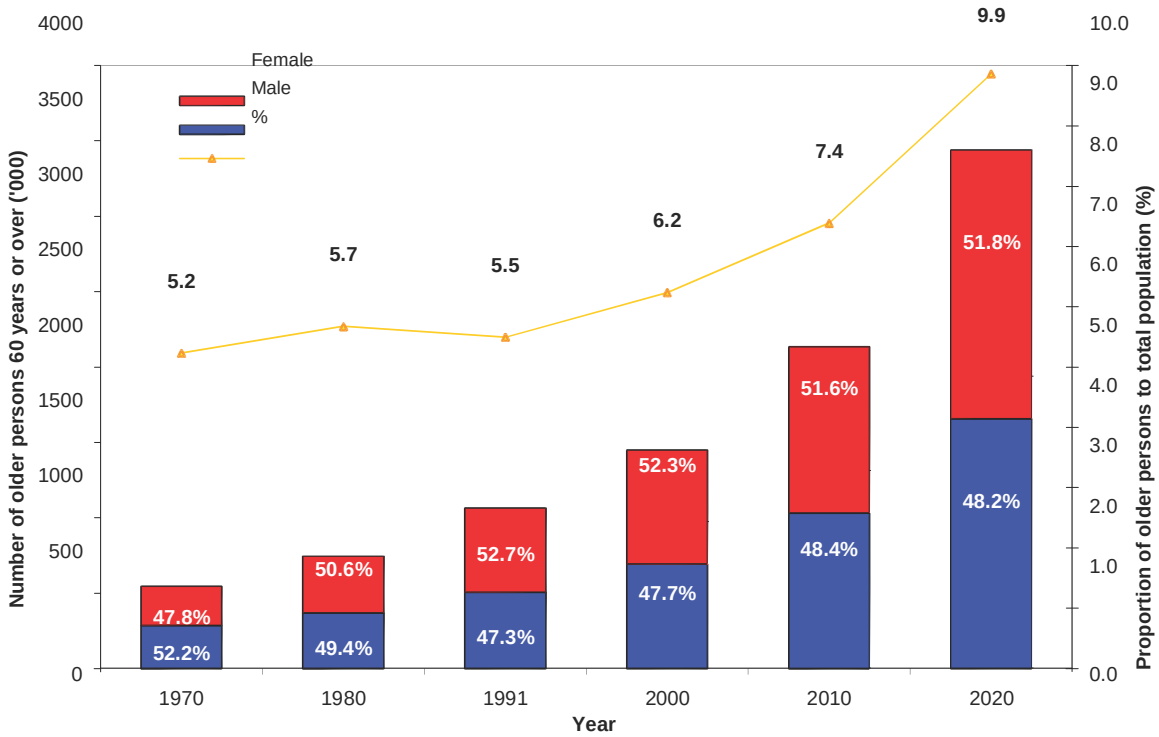


Figure 1. Trend of population ageing in Malaysia, 1970 – 2020 (1).

Population ageing is said to occur when changes in a country's life expectancy and birth rate results in a shift in population distribution towards older age groups. This usually arises as a natural consequence of socioeconomic development from a pre-industrial to an industrialised state. In Malaysia, the proportion of older persons 60 years and above is rapidly increasing and expected to exceed 10% of the total population by 2020 (*Figure 1*) (1).

The proportion of females in the population is also expected to rise due to a longer lifespan.

The Demographic Transition (DT) model suggests that developing countries pass through a series of population stages during which mortality and fertility rates both fall as a result of better healthcare, nutrition, education, availability of contraception, and

the entrance of women into the labour force (2). The four stages from the DT model can be represented by population pyramids (Figure 2).

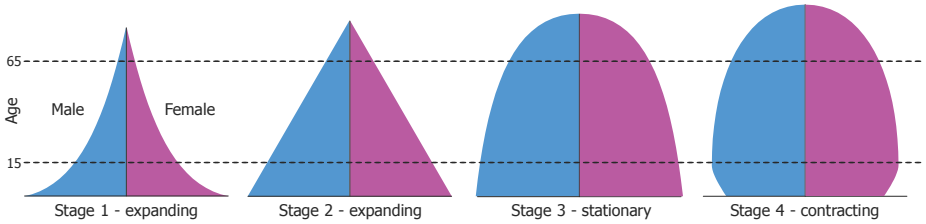
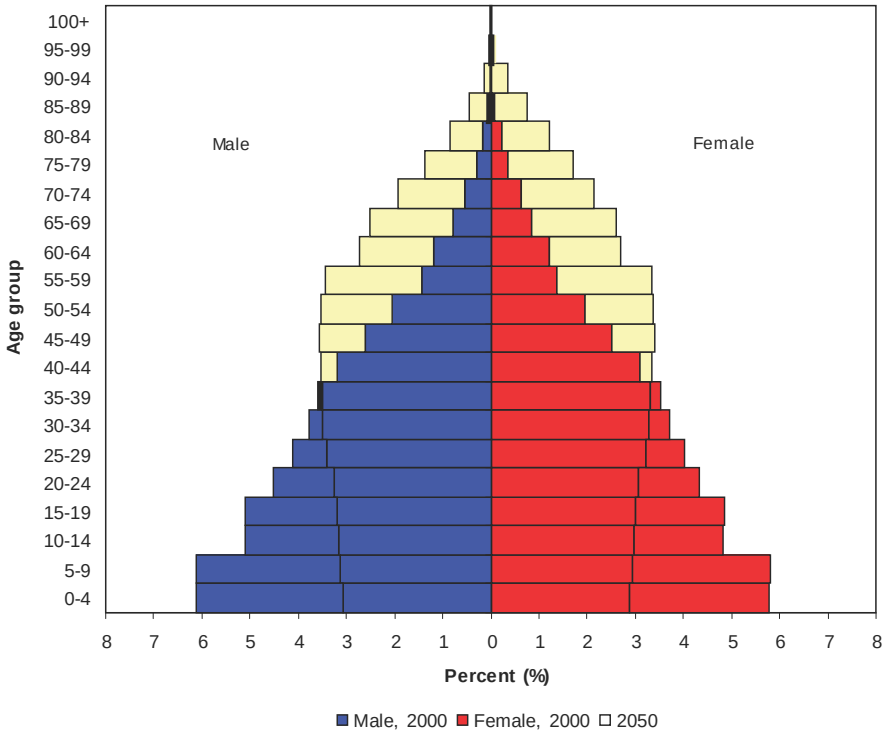


Figure 2. Population pyramids for 4 stages of the demographic transition model (2).

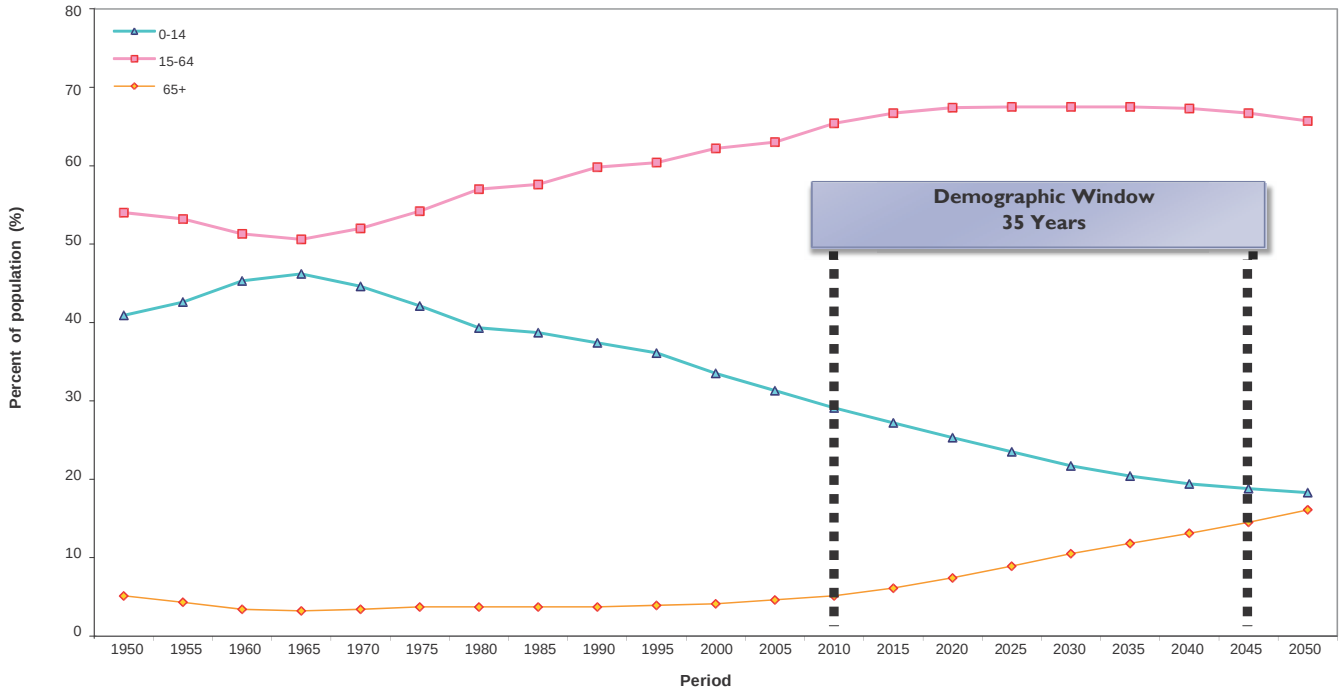
In Stages 1 and 2, the base of the pyramid is broad, with a high proportion of young people, a small proportion of older people, and a growing population. In Stage 3, both fertility and mortality rates are balanced, and population growth is stationary. By Stage 4, the population is ageing with low fertility and mortality rates, a small proportion of young people, and a growing proportion of older people. Malaysia presently is in stage 2, but is expected to rapidly progress to Stage 4 by 2050 (Economic Planning Unit 2009) (*Figure 3*).



Source: Economic Planning Unit 2009

Figure 3. Population pyramids, Malaysia 2000 and 2050 (3).

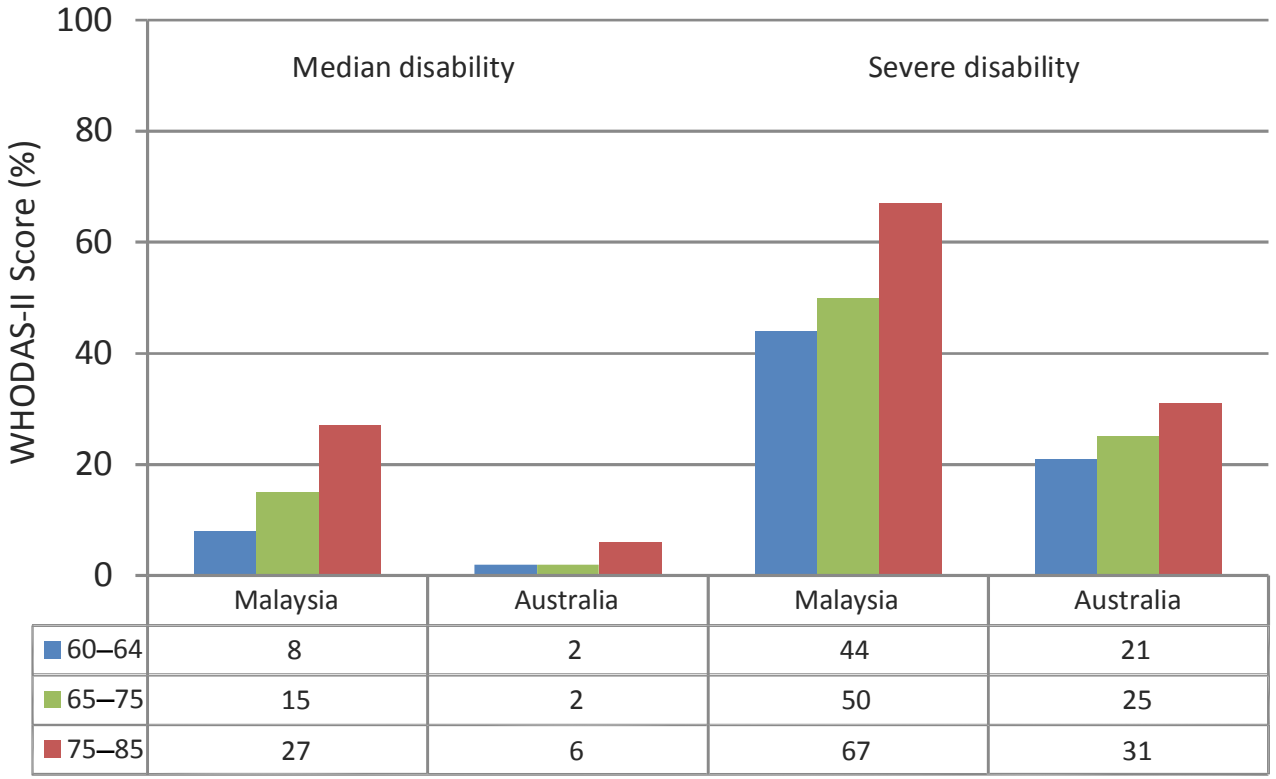
The Importance of the Demographic Window



Source : UNDP 2011; Batelle 2012

Figure 4. Population aged 0 – 14, 15 – 64 and 65+ in Malaysia, 1950 – 2050 (4, 5).

As a country progresses through the stages in the DT model, there will be a period during which the proportion of population within the working age group is particularly high. During this period, which is called the Demographic Window (DW), the ratio of population not in the labour force (dependent) to those in it (productive) is relatively low. This ratio is called the dependency ratio, and indicates the burden on the productive part of the population to maintain the economically dependent, such as children and the elderly. When a country has a high dependency ratio, a significant proportion of the government's expenditure will be channelled towards maintaining health services, pensions, and educational facilities. In contrast, a country with a low dependency ratio will have more available resources which can be directed towards socioeconomic development.



	Malaysia	Australia	Malaysia	Australia
60–64	8	2	44	21
65–75	15	2	50	25
75–85	27	6	67	31

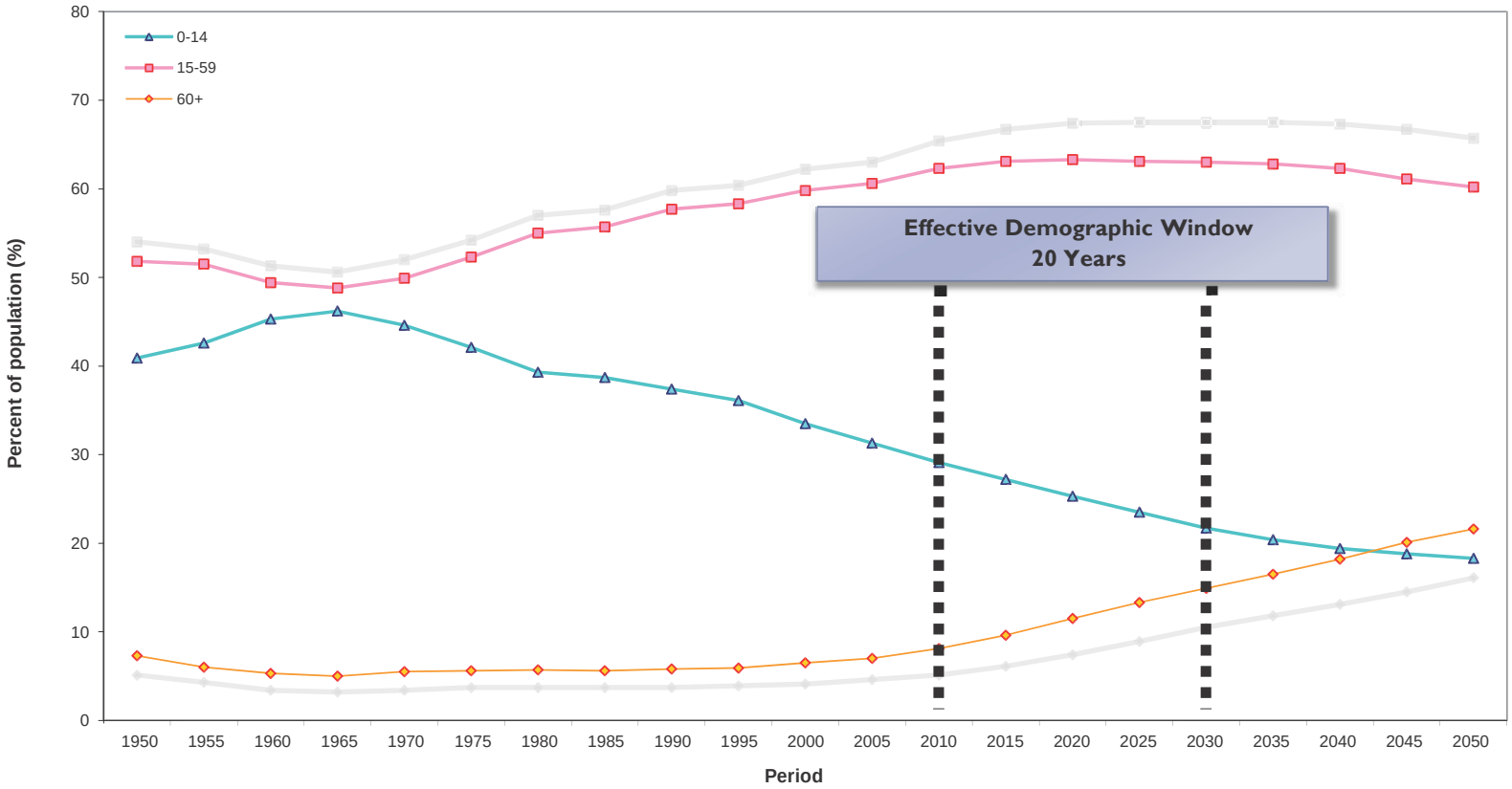
Source: National Statistic of Health

Figure 5. Comparison of WHODAS-II scores for median and severe disability between Malaysia and Australia (7).*

** Wellness National Data 2009 – Institute of Gerontology, UPM.*
Median disability = 50th percentile, Severe disability = 90th percentile.

The UN Population Department defines the DW as the period in which the proportion of children and youth under 15 years falls below 30% and the proportion of people 65 years and older is still below 15%. The DWs for major regions are as follows: Europe 1950-2000, North America 1970–2015, China 1990–2025, and India 2010–2050. For Malaysia, the DW is expected to last from 2010 – 2045 (*Figure 4*) (5).

The standard DW definition presumes that the working population is productive up to the age of 65 years old following the trend in developed countries. In Malaysia, there is strong evidence that the productive life of older people is limited by disability and a relatively early retirement age. For many years, the retirement age for the public sector was set at 55 years, and it is only recently that measures have been taken to increase it to 60 years (6). In addition,



Source : UNDP 2011; Batelle 2012

Figure 6. Population aged 0 –14, 15–60 and 60+ in Malaysia, 1950–2050.

local data has shown that for comparable age cohorts, older people in Malaysia experience more disability than their peers in other countries such as Australia (*Figure 5*) (7).

If the working population in Malaysia is productive only until the age of 60 years old, this will translate into a shortened effective DW of only 20 years (*Figure 6*). This is in contrast to the Western democracies which have had long DWs of about 40–50 years. Malaysia needs to make necessary changes now to adapt otherwise the productivity gains from its DW will be lost by mid-century as a result of pressures from an ageing population.

Chronic Non-Communicable Diseases and Disability

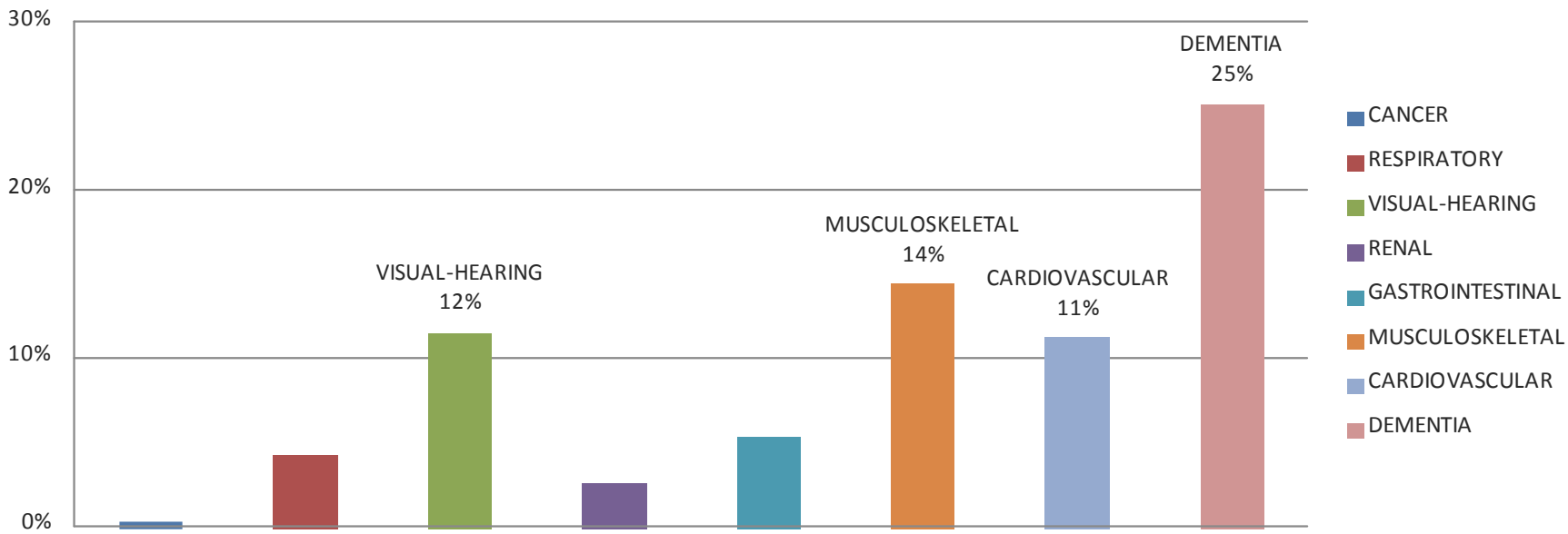


Figure 7. Population attributable risk for WHODAS-II disability in older Malaysians.

** Combined MHQoL National Data 2006, Psychological Well-Being National Data 2007, Wellness National Data 2009 — Institute of Gerontology, UPM.*

Based on nationwide data on community-dwelling older people in Malaysia, the top four chronic disease groups which cause disability are dementia, musculoskeletal diseases, visual-hearing impairments, and cardiovascular diseases (*Figure 7*).

75% of older people suffer from at least one of these four chronic disease groups, with 35% having two or more diseases simultaneously. Usage of all types of healthcare resources increases with degree of disability, with a striking rise in public healthcare usage (*Figure 8*).

According to the International Classification of Functioning, Disability, and Health model from the World Health Organisation, disability is said to arise from pre-existing health conditions in an

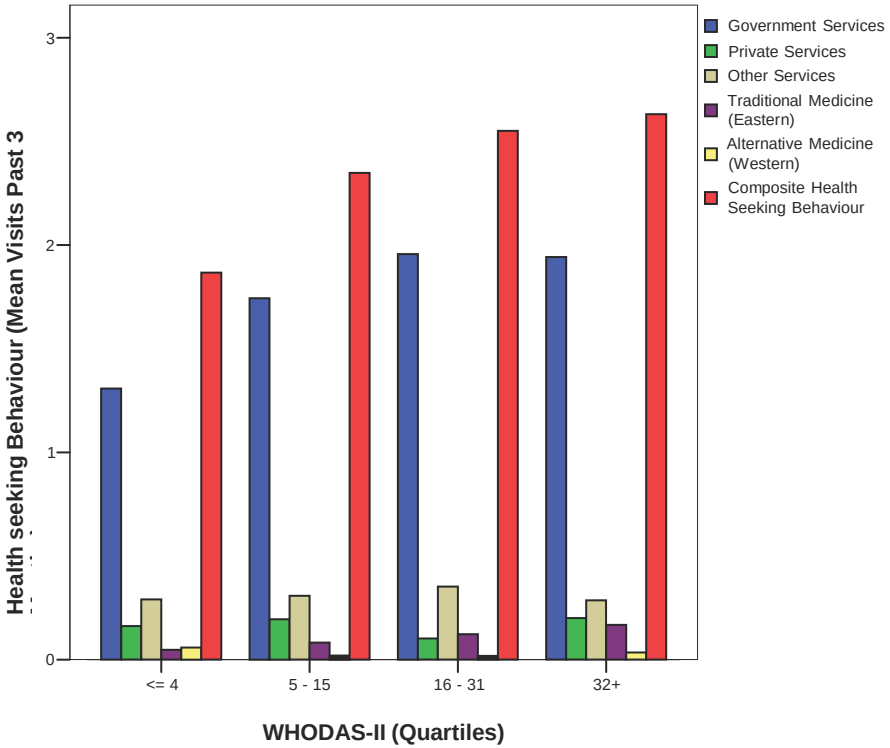


Figure 8. Healthcare usage by older Malaysians according to degree of disability.

** Combined MHQoL National Data 2006, Wellness National Data 2009 — Institute of Gerontology, UPM.*

individual, and can restrict participation in any area of life (8, 9). An older person with some level of disability may find difficulty with formal employment, and be unable to help with looking after young family members. Those with a high level of disability become dependent, and require care and support from others.

Most of the disability in an older person occurs as a result of a lifetime accumulation of impairments from chronic diseases. During early life, risk factors for development of chronic diseases

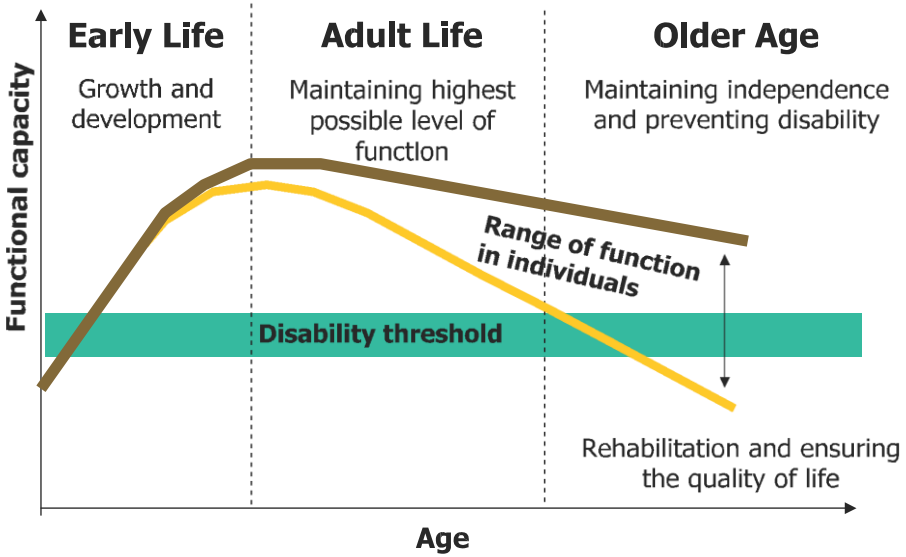


Figure 9. Relationship between disability and chronic diseases from a lifetime perspective (10).

predominate. These diseases begin to manifest in adult life, and eventually cause functional impairments which contribute to disability in old age (*Figure 9*).

When an individual's level of disability exceeds the disability threshold for that population, that individual is then unable to function independently in society, requires care from others, and becomes what is conventionally known as "disabled". Local Malaysian data on the Katz basic activities of daily living (ADL) supports the concept of a disability threshold (Fig. 10). The implication is that a relatively small change in an individual's level of disability who is close to the threshold can render that person either functionally independent or disabled.

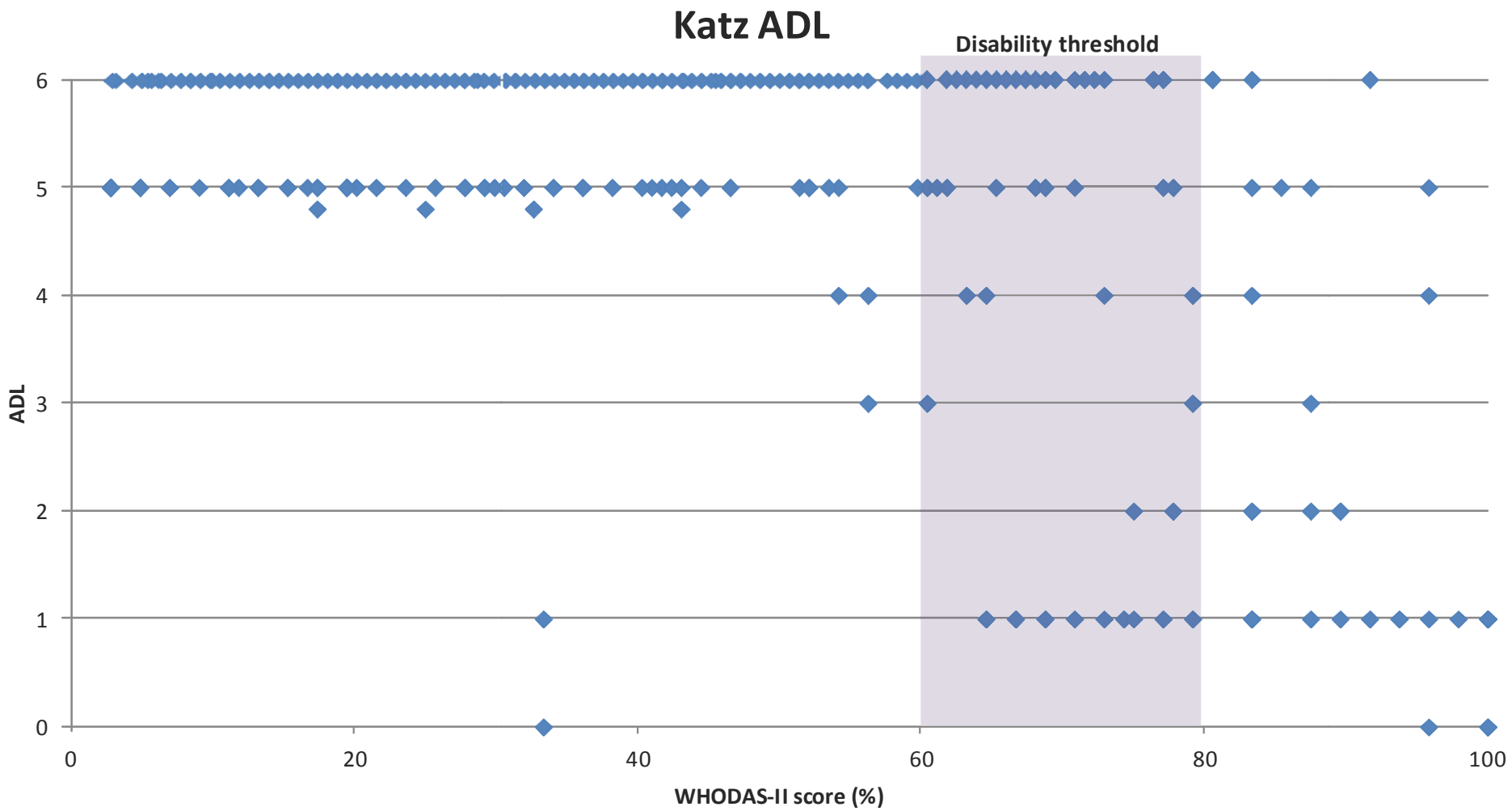


Figure 10. Disability threshold based on the Katz activities of daily living.

** MHQoL National Data 2006 - Institute of Gerontology, UPM.*

The Role of Regenerative Medicine in Reversing Disability

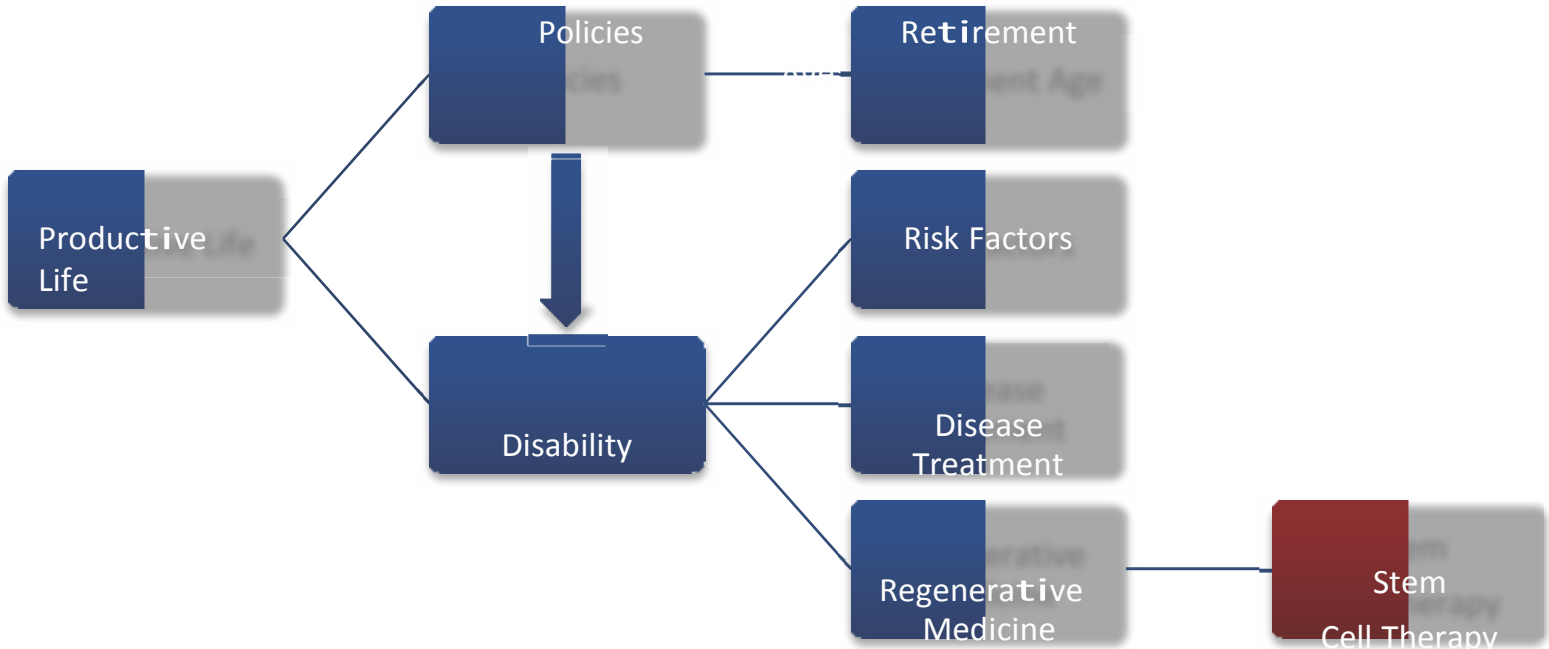


Figure 11. The hierarchy of factors affecting the productive life of older people in Malaysia.

A reduction in disability among older Malaysians coupled with appropriate policy changes to give them the option to work later in life, can extend the productive lifespan of older people, and lengthen the country's effective DW. This reduction in disability is traditionally accomplished by targeting risk factors and better treatment of chronic diseases. Disability can also be mitigated by disabled-friendly policies, building designs, and assistive technology (*Figure 11*).

Regenerative medicine however provides an alternative avenue for achieving this, by regenerating damaged tissues and organs, restoring lost function, and hence reversing existing disability. Stem cell therapy is a sub-set of regenerative medicine, and is a

disruptive technology which has the potential to reshape the disability profile of older Malaysians (*Figure 11*) (11). Stem cell research in Malaysia should be directed towards developing treatments which target the top local causes of disability, and reducing the costs involved so that they are affordable for a large segment of the population.

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There are a number of companies and health institutions which provide stem cell therapy services in Malaysia

Developed countries are strong in laboratory based stem cell research, while developing countries have an advantage in conducting clinical trials

The researchers who are active in stem cell research constitute about 0.5% of the total research manpower in Malaysia

The pattern of stem cell research locally is more typical of a developed country

Stem Cell Research Worldwide

In recent years, the increasingly globalised nature of healthcare research has led to outsourcing of clinical trials from high cost developed nations to developing countries where the research infrastructure and local technical skills are less advanced. This outsourcing takes advantage of the high disease burden, low cost of research, and the varying standard of ethical review and regulation in developing countries (1).

In the developed world, regulatory control is usually strict and clinical trials are both expensive and difficult to conduct without a strong base of pre-clinical research. Existing laboratories and funding infrastructure are usually well developed, and this gives a strong advantage when conducting pre-clinical work. For the developing world, regulatory control is much more permissive and subjects for clinical trials are readily available in larger numbers. Laboratory work is however more difficult to perform as the research infrastructure is usually quite basic, and the researchers less experienced.

TABLE 1. CONFERENCES AND WORKSHOPS ON STEM CELL RESEARCH.

Name	Date	Venue
Adult stem cell workshop.	20–23 Oct 2003	HUKM
2nd National Tissue Engineering and Regenerative Medicine Scientific Meeting, 2nd MTERMS 2008.	22–23 July 2008	HUKM
Cell based therapy workshop.	10–14 Nov 2008	HUKM
Seminar on Advances in Stem Cell Therapy Current Research & Future Applications ASCT 2009.	12–13 Dec 2009	IMU
3rd National Tissue Engineering and Regenerative Medicine Scientific Meeting, 3rd MTERMS 2010.	13–14 Oct 2010	UPM
Annual International Conference on Stem Cell Research SCR 2011.	25–26 Apr 2011	Hotel Equatorial Penang

Appendix tables 2-IA and 2-IB list the companies and health institutions that provide stem cell therapy services in Malaysia. About half of the companies specialise in cord blood banking services.

A number of conferences and workshops have been held on stem cell research locally (*Table 1*).

There are about 110 researchers in local institutions that are active in the field of stem cell research, which is about 0.5% of the total research manpower in Malaysia (approximately 21,500 full time equivalent staff) (2) The universities with the largest manpower in this field are Universiti Kebangsaan Malaysia (UKM), Universiti Putra Malaysia (UPM), Universiti Malaya (UM), and Universiti Sains Malaysia (USM), while Stempeutics has the largest research

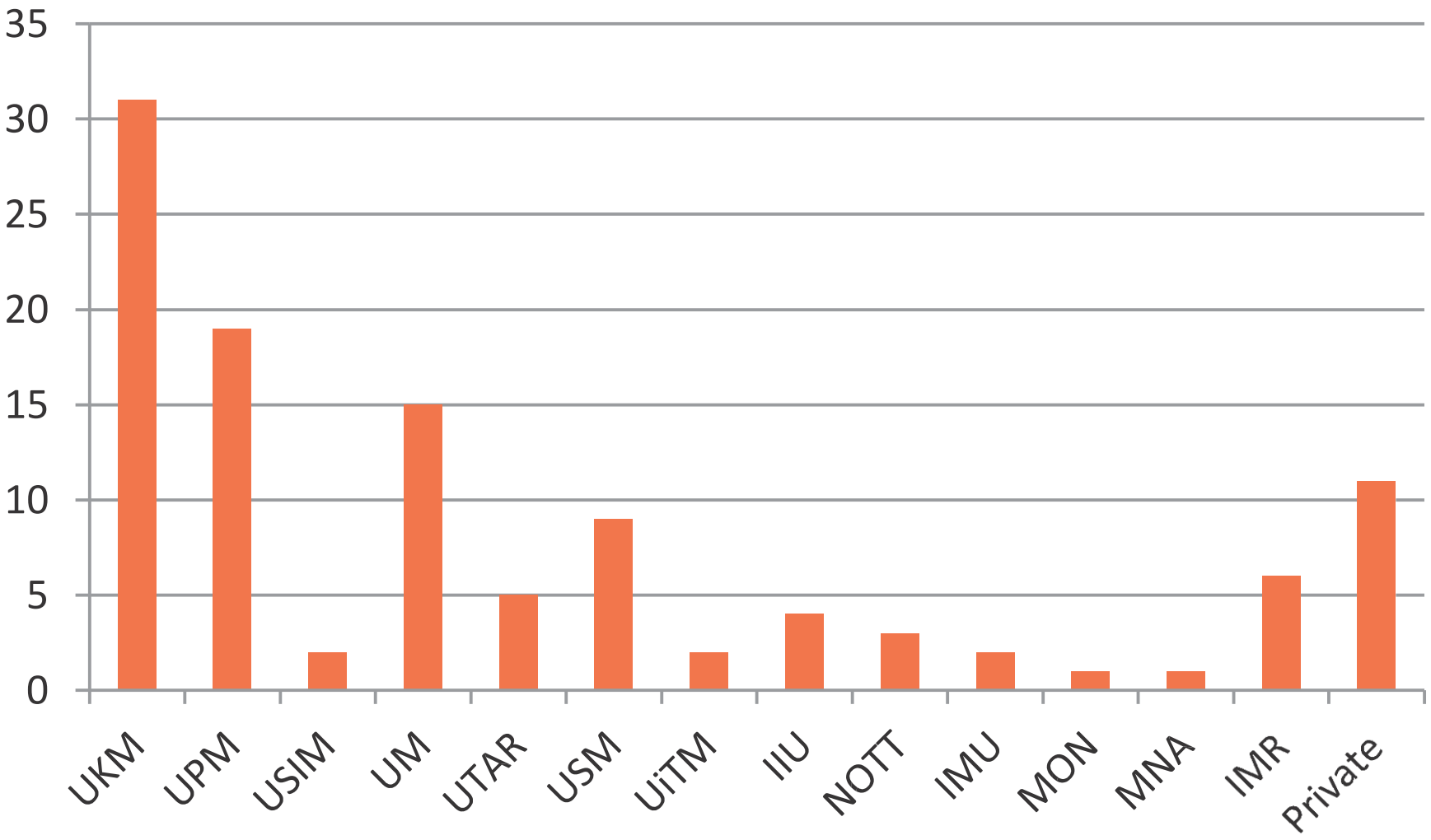

Figure 1. Researchers in the field of stem cell research by institution.

** Information compiled from websites and research management centres of the respective institutions.*
*** See Appendix Tables 2-II and 2-III for the institution abbreviations.*

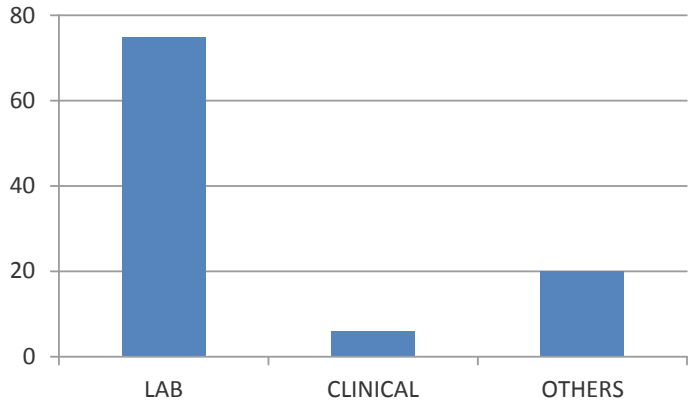

Figure 2. Journal articles by type.

** LAB - pre-clinical and laboratory research, CLINICAL - clinical trials, OTHERS - includes review articles.*
*** Indexed by Pubmed Medline as of March 2012. Note: the list may not be comprehensive, and includes only articles where the corresponding institution is in Malaysia.*

contingent amongst the commercial entities (*Appendix Table 2-II*, *Figure 1*).

A search through Medline turned up about 100 journal articles on stem cell research by Malaysian institutions over the past 10 years, with a cumulative impact factor of 130 (*Appendix Table 2-III*). Of these, 74% are based on pre-clinical research, 6% on clinical trials, and the remaining 20% review articles (*Figure 2*). From the distribution of articles, it can be seen that the pattern of research follows that of developed countries.

Of the universities, UKM, UM, and UPM have the highest output for article count and impact factor, with UKM dominating the field (*Figure 3*). However, when the output is measured per researcher, all three universities perform similarly (*Figure 4*). Among the commercial entities, Stempeutics has the highest output and productivity, and even outperforms the major universities where productivity is concerned (*Figure 4*). This is in part due to a ctive collaboration and funding from the Ministry of Health.

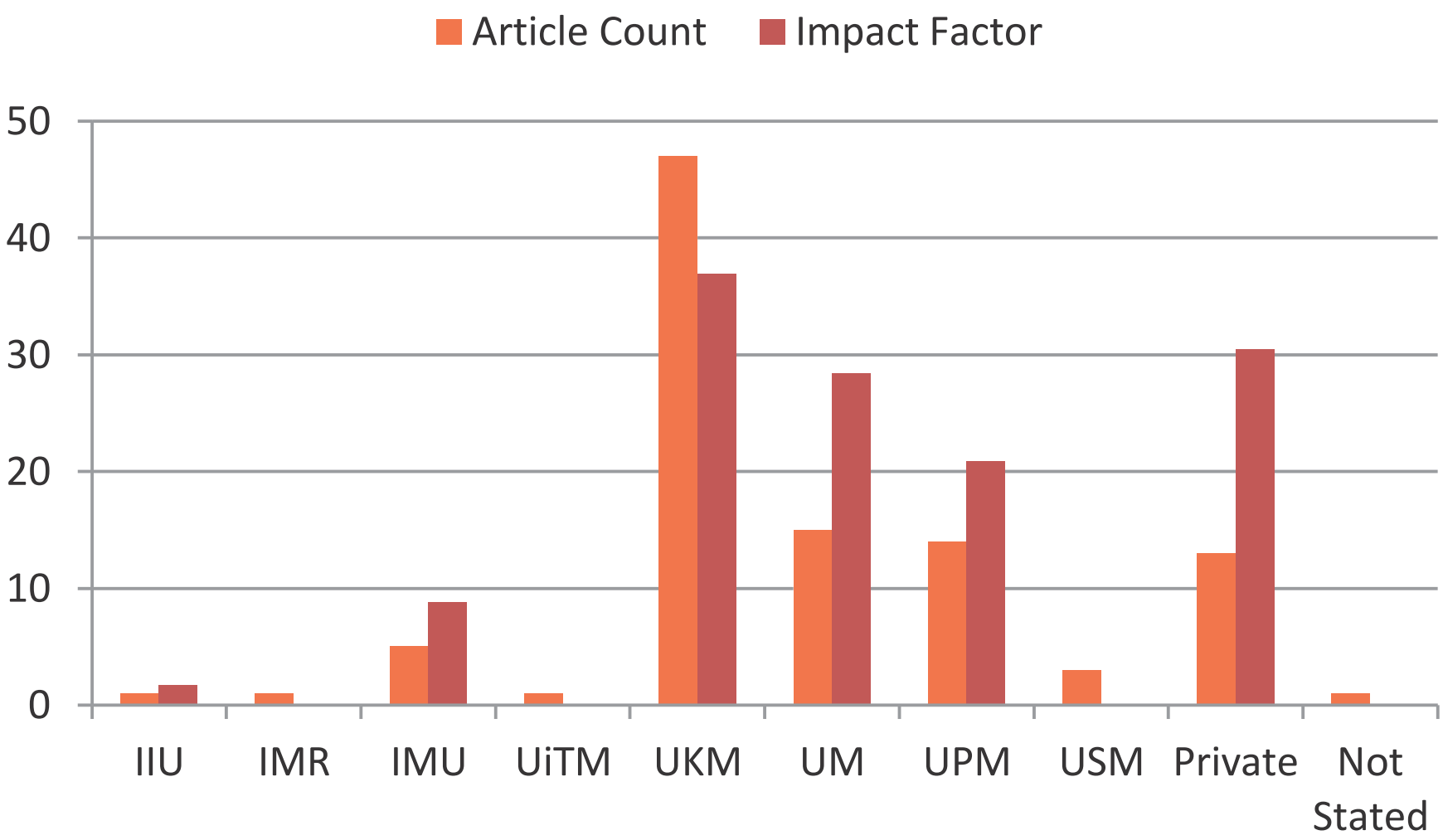

Figure 3. Journal count and cumulative impact factor for articles on stem cell research by institution.

** Indexed by Pubmed Medline as of March 2012. All impact factors (IF) from Thomson ISI Web of Knowledge 2011 database.*
*** Note: the list may not be comprehensive, and includes only articles where the corresponding institution is in Malaysia. See Appendix Tables 2-II and 2-III for the institution abbreviations.*

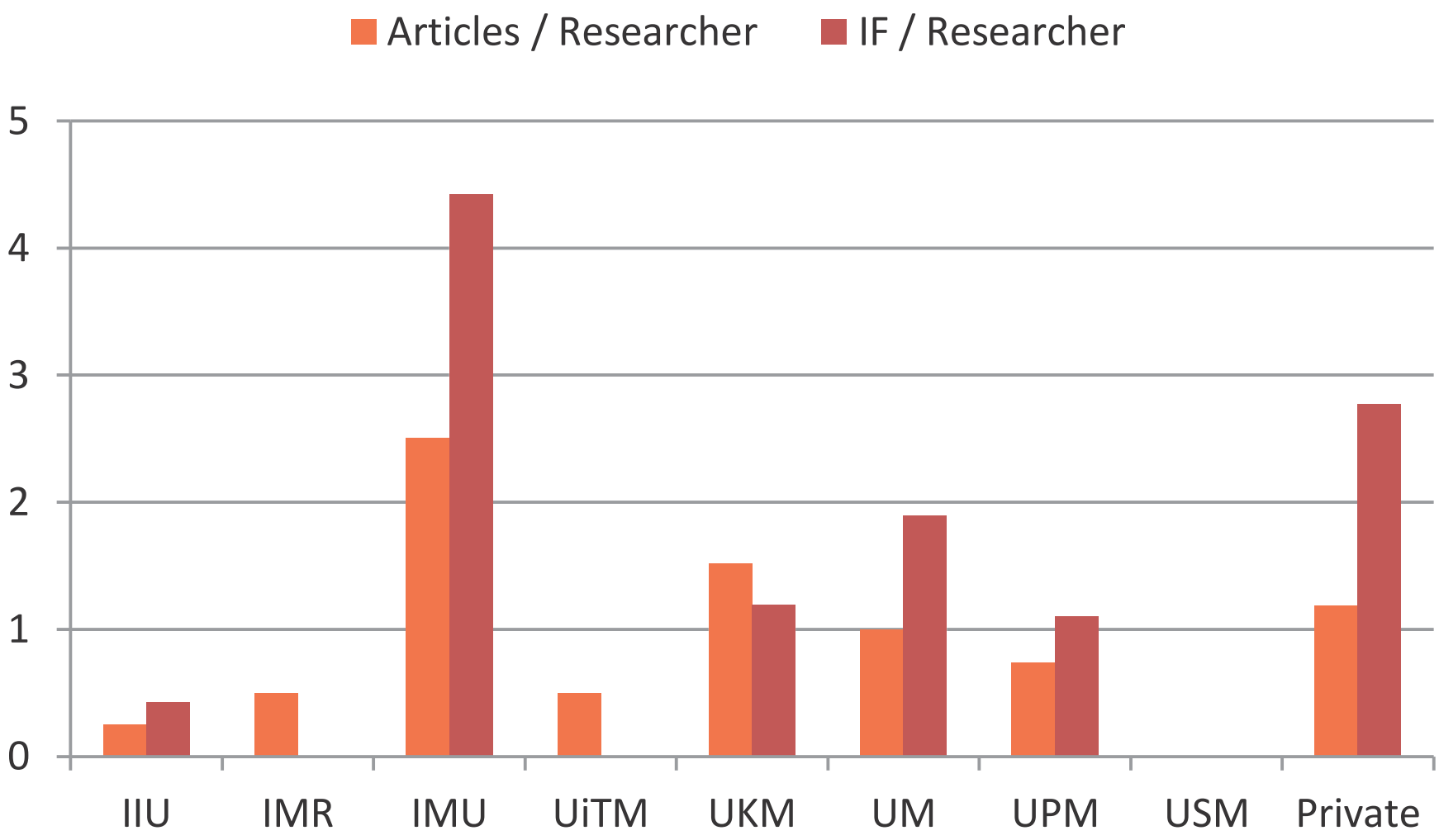

Figure 4. Article count and impact factor (IF) for stem cell research per researcher by institution.

** Indexed by Pubmed Medline as of March 2012. All impact factors (IF) from Thomson ISI Web of Knowledge 2011 database.*
*** Note: the list may not be comprehensive, and includes only articles where the corresponding institution is in Malaysia. See Appendix Tables 2-II and 2-III for the institution abbreviations.*

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Ethical and religious issues arise from embryonic stem cell research and cloning technology
Religious and regulatory authorities are more tolerant of therapeutic cloning, in contrast to reproductive cloning
Most countries with an established or rapidly growing biotechnology industry allow embryonic stem cell research and therapeutic cloning
Malaysian guidelines allow embryonic stem cell research and therapeutic cloning with some restrictions

Ethical and Religious Issues for Stem Cell Research

TABLE 1. RELIGIOUS VIEWS ON EMBRYONIC STEM CELL RESEARCH AND THERAPEUTIC CLONING (1–8).

	Embryonic research	Therapeutic cloning	Reproductive cloning
Islam	Allowed	Allowed	Not allowed
Catholic Christian	Not allowed	Not allowed	Not allowed
Non-Catholic Christian	Not allowed	Not allowed	Not allowed
Buddhism	Allowed	Allowed	Not allowed
Hinduism	Allowed	Allowed	Not Stated
Sikh	Not allowed	Not allowed	Not allowed
Taoist	Not allowed	Not allowed	Not allowed

** Religious views where there is no central authority are diverse, and the above table refers to prevailing opinion among adherents.*

Most of the controversy surrounding stem cell research centres on embryonic stem cell research and cloning technology. There is less of an ethical problem with xenotransplantion of animal cells as tissues and organs from these sources have already been used for many years in clinical treatment (e.g. skin substitutes for burns, prosthetic heart valves).

The benefits of using embryonic rather than adult stem cells are that:

(1) These cells are relatively easy to grow in culture
(2) They are totipotent and can form all cell types found in the body
(3) These cells can be easily isolated from the embryo; and
(4) They can be used where adult stem cells are difficult to isolate (e.g. neural tissue)

The benefits of therapeutic cloning (somatic cell nuclear transfer) are more limited, and come from producing an embryonic stem cell line that is genetically identical to the patient, thus reducing the chance for graft rejection. In contrast, reproductive cloning has no clear medical benefits.

Regulatory authorities and funding bodies have a duty to weigh the potential benefits from these techniques against the ethical and religious concerns that arise from their use. The main issue from embryonic stem cell research and therapeutic cloning is that these techniques require the destruction of an embryo that could potentially form into a new human being. In addition, therapeutic cloning is seen by some as the first step towards reproductive cloning, which is the generation of a child that is genetically identical to the parent.

Religious bodies have diverse views on both these techniques, but in general are more tolerant of therapeutic cloning provided it is done under regulatory guidance which prohibits crossing over into reproductive cloning (*Table 1*). Most religions agree that reproductive cloning is morally and ethically wrong (1).

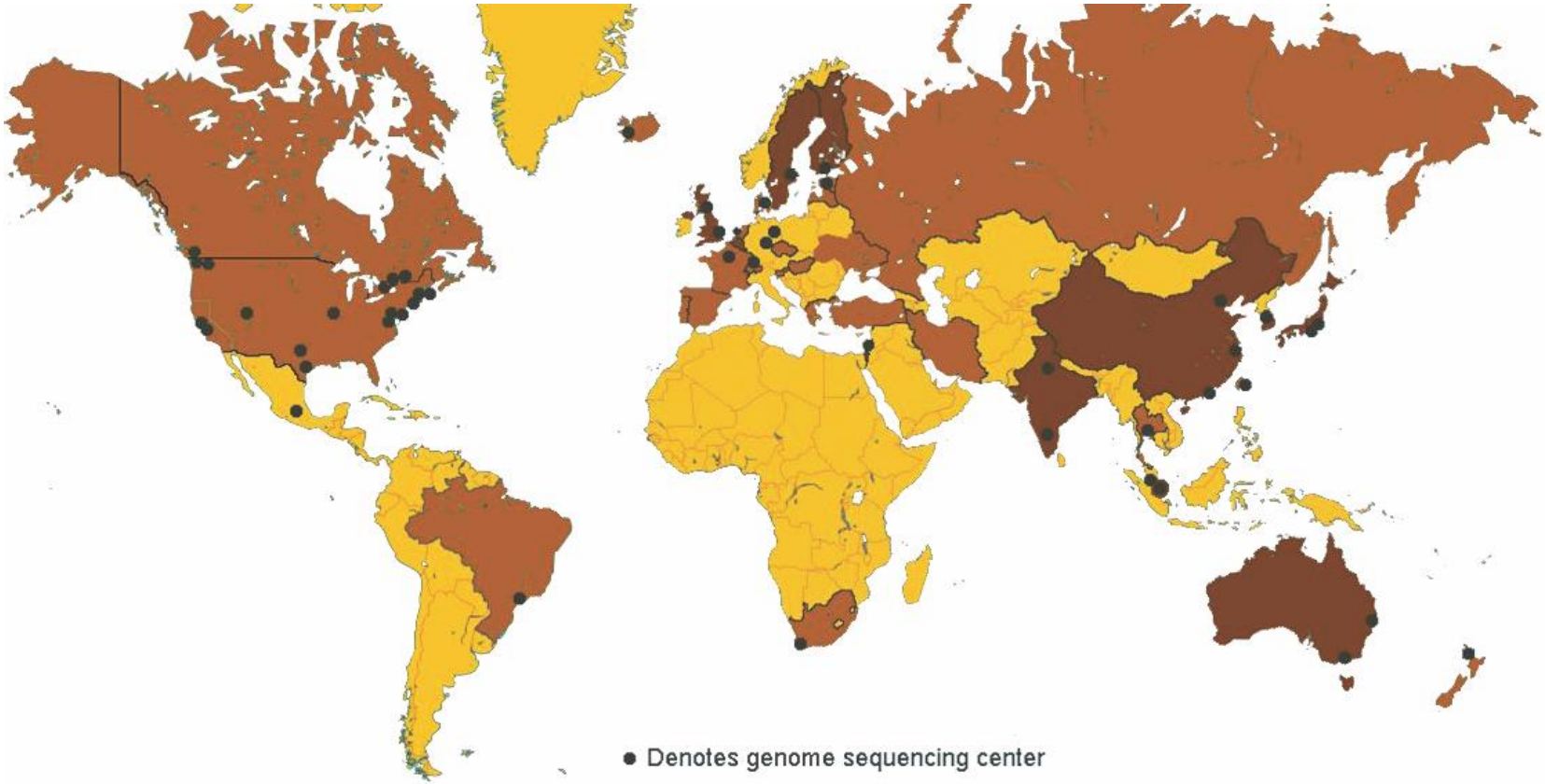
Regulatory Framework for Stem Cell Research Worldwide

TABLE 2. GOVERNMENT POLICIES ON EMBRYONIC STEM CELL RESEARCH AND THERAPEUTIC CLONING (10–12).

Country	Embryonic research	Therapeutic cloning	Reproductive cloning
United States*	Varies	Varies	Varies
United Kingdom	Allowed	Allowed	Not allowed
China	Allowed	Allowed	Not allowed
India	Allowed	Allowed	Not allowed
Singapore	Allowed	Allowed	Not allowed

** No federal regulation has restricted stem cell research of any kind, but state laws vary*

The regulatory stance of countries active in stem cell research generally mirrors the religious views of their population. Countries with a strong Catholic Christian tradition have the most restrictive policies, while those with secular traditions have the most liberal regulations (*Table 2, Figure 1*). In addition, countries with a large established or rapidly growing biotechnology industry tend to have more permissive policies governing stem cell research (see chapter 4 for more details).



Permissive policy - embryonic stem cell research permitted, including therapeutic cloning (somatic cell nuclear transfer)
Flexible policy - embryonic stem cell research restricted to fertility clinic embryos no longer needed for reproduction
Restrictive or no policy - either outright prohibition on embryonic stem cell research or restriction to established cell lines

Figure 1. *Government policy on embryonic stem cell research and therapeutic cloning (9).*

Regulatory Framework for Stem Cell Research In Malaysia

TABLE 3. MALAYSIAN GUIDELINES ON EMBRYONIC STEM CELL RESEARCH AND THERAPEUTIC CLONING.

Authority	Embryonic research	Therapeutic cloning	Reproductive cloning
Ministry of Health	Allowed*	Allowed*	Not allowed
Medical Council	Allowed*	Not Stated	Not stated

** Some restrictions apply*

Research on stem cells in Malaysia is presently not covered by any legislation. Provision of stem cell therapy services by health providers is also similarly not restricted provided that the *Private Healthcare Facilities and Services Act (1998, Act 586)* is complied with (13).

The Ministry of Health has issued a set of guidelines covering stem cell therapy, and the Malaysian Medical Council is also in the process of finalising its own guidelines (*Table 3*). While these are not legally binding legislation, the regulatory authorities will take these into consideration should any problems arise in the future (14). The Ministry of Health guidelines also prohibit xenotransplantation, except in cases where clear evidence exists for benefit to the patient.

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Government support for stem cell research in Malaysia is vital to help it succeed
Compared to other countries, policy in Malaysia on embryonic and xenotransplant cell research is relatively restrictive
Research funding and human capital development in Malaysia is very poor compared to its economic strength
This puts Malaysia at a distinct disadvantage when competing in a knowledge intensive field such as regenerative medicine and stem cell research
Stem cell therapy is poised to be the major life science research area within the next five years

Policy and Funding For Stem Cell Research Worldwide

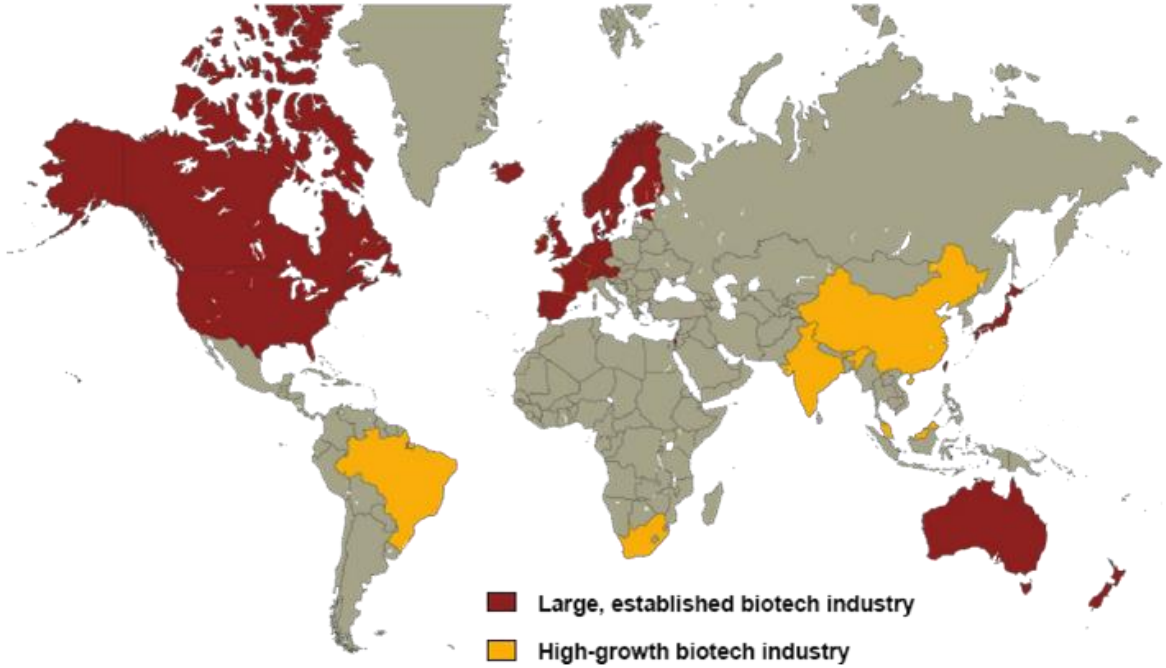


Figure 1. Status of the biotechnology industry worldwide (2).

For a relatively young area of investigation such as stem cell research, success is heavily influenced by the degree of government support. This support can be in the form of funds, a permissive regulatory environment, and a good research infrastructure. Industry and venture capital grants are more focused on the later stages of the research cycle where a product is almost ready for commercialisation. In contrast, government sources of funding predominate in basic research, and this is especially important in stem cell research where the physiological processes that govern its use are still under investigation.

The use of autologous cells for stem cell therapy is fairly well accepted internationally. Embryonic and xenotransplant cell sources however, face varying degrees of regulatory restrictions depending on jurisdiction, because of the ethical and religious issues surrounding their use. In Malaysia, the National Guidelines

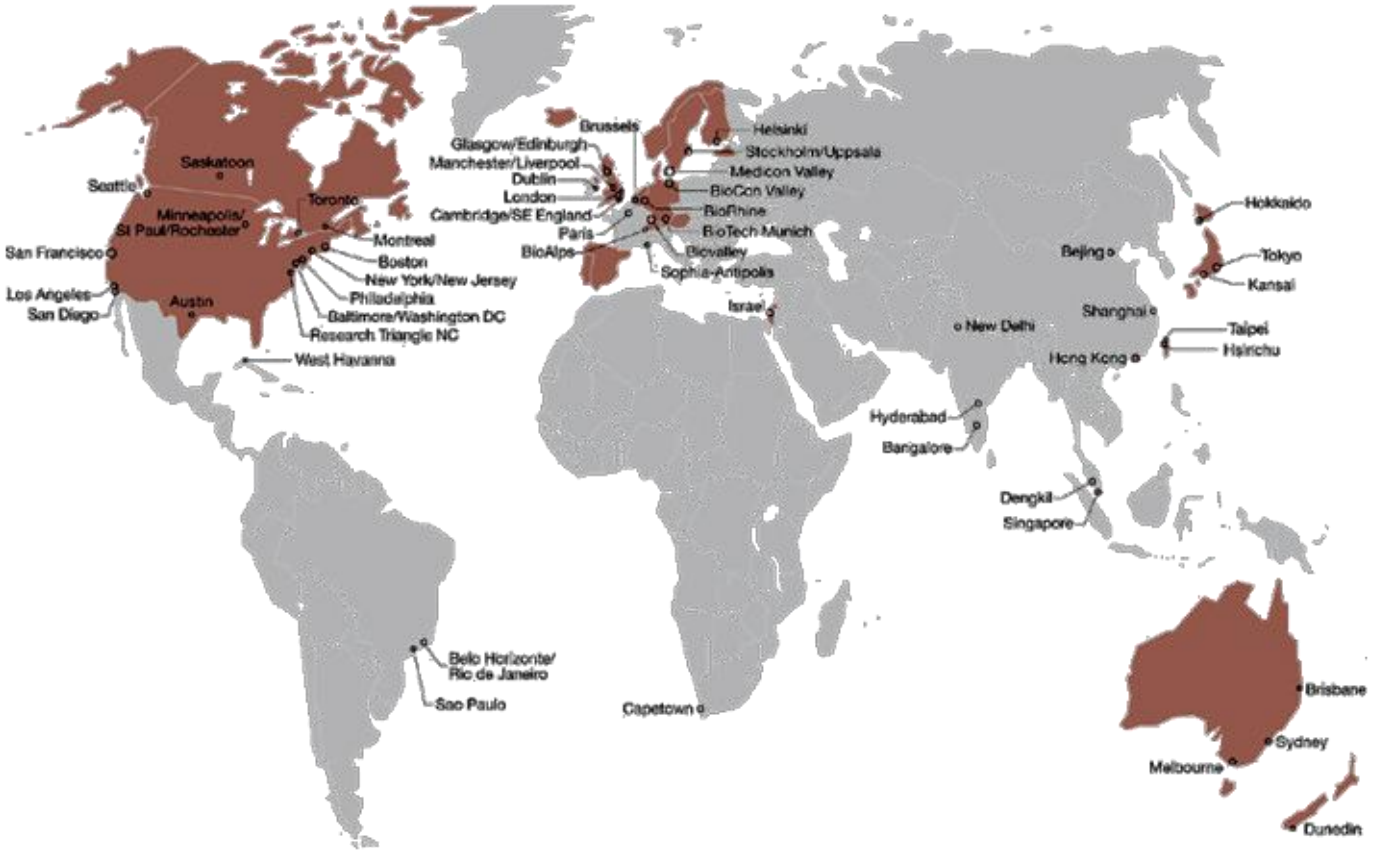


Figure 2. Global biotechnology clusters (3).

** Countries in brown rank highly in the Growth Competitiveness Index. Black circles represent biotechnology and life-sciences clusters.*

for Stem Cell Therapy and Research outline the circumstances in which embryonic and xenotransplant cell research can be undertaken, and is relatively restrictive compared to other countries (see chapter 3 for more details) (1).

The research infrastructure for biotechnology in developed nations is very advanced, especially those with a large established biotechnology industry (*Figure 1, 2*). Most of the cutting edge research and development takes place in purpose-built science parks or research clusters dedicated to life sciences and biotechnology (*Figure 2*).

While Malaysia has a rapidly growing biotechnology industry, funding for research and development is relatively poor compared

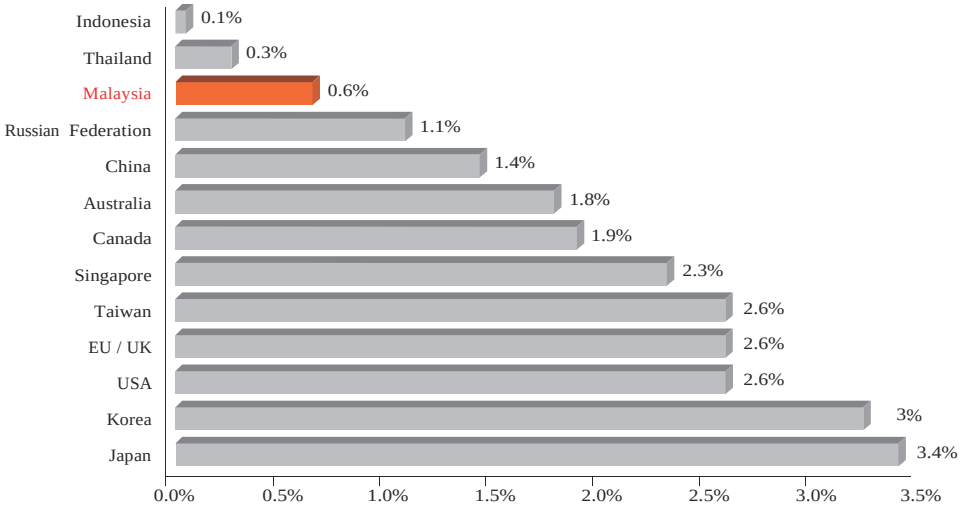


Figure 3. Research and development expenditure as a proportion of GDP (6).

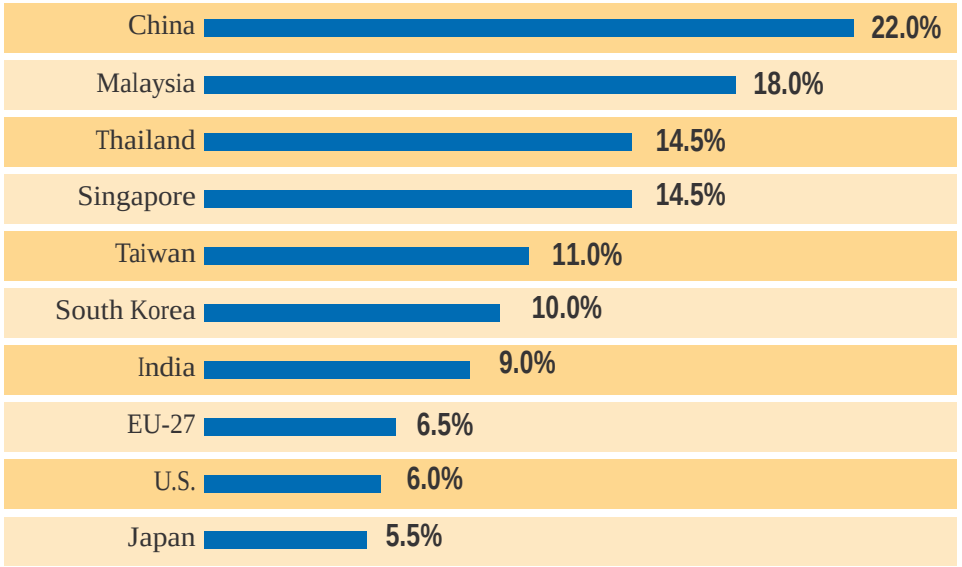


Figure 4. Average annual research and development growth, 1996–2007 (7).

to the country's economic strength (*Figure 3*). This however has been increasing rapidly in the last decade, albeit from a small base (*Figure 4, Table 1*). Under the 9th Malaysia Plan, RM32 million was allocated over five years to strengthen stem cell and blood bank activities throughout the country (4). However, this was dwarfed by the US$5.1 billion that the National Institutes of Health in the United States spent on stem cell research for the equivalent period (2006–2010) (5). About 30% of research funding in Malaysia comes from government grants, which is consistent with the trend in most countries (*Figure 5*).

Malaysia's human capital investment for research is one of the lowest in the world, with the number of researchers per population being less than 10% of the equivalent figure in Singapore (*Figure 6*). The overall proportion of scientists and engineers is also very low, and this puts the country at a distinct disadvantage when competing in a knowledge intensive field such as regenerative medicine and stem cell research (*Figure 7*).

TABLE 1: FORECAST GROSS EXPENDITURE ON RESEARCH AND DEVELOPMENT (GERD) (7)

		2010			2011			2012		
		GDP PPP Bil, US$	R&D as % GDP	GERD PPP	GDP PPP Bil, US$	R&D as % GDP	GERD PPP	GDP PPP Bil, US$	R&D as % GDP	GERD PPP
1	United States	14,660	2.83%	415.1	15,203	2.81%	427.2	15,305	2.85%	436.0
2	China	10,090	1.48%	149.3	11,283	1.55%	174.9	12,434	1.60%	198.9
3	Japan	4,310	3.44%	148.3	4,382	3.47%	152.1	4,530	3.48%	157.6
4	Germany	2,940	2.82%	82.9	3,085	2.85%	87.9	3,158	2.87%	90.6
5	South Korea	1,459	3.36%	49.0	1,549	3.40%	52.7	1,634	3.45%	56.4
6	France	2,145	2.21%	47.4	2,227	2.21%	49.2	2,282	2.24%	51.1
7	United Kingdom	2,173	1.81%	39.3	2,246	1.81%	40.7	2,305	1.84%	42.4
8	India	4,060	0.80%	32.5	4,472	0.85%	38.0	4,859	0.85%	41.3
9	Brazil	2,172	1.10%	23.9	2,294	1.20%	27.5	2,402	1.25%	30.0
10	Canada	1,330	1.95%	25.9	1,387	1.95%	27.0	1,429	2.00%	28.6
11	Russia	2,223	1.03%	22.9	2,367	1.05%	24.9	2,491	1.08%	26.9
12	Italy	1,774	1.27%	22.5	1,824	1.30%	23.7	1,849	1.32%	24.4
13	Taiwan	822	2.30%	18.9	883	2.35%	20.7	938	2.38%	22.3
14	Australia	882	2.21%	19.5	917	2.25%	20.6	958	2.28%	21.8
15	Spain	1,369	1.38%	18.9	1,409	1.40%	19.7	1,440	1.42%	20.4
16	Sweden	355	3.62%	12.9	379	3.62%	13.7	398	3.62%	14.4
17	Netherlands	677	1.84%	12.5	703	1.87%	13.1	720	1.90%	13.7
18	Switzerland	324	3.00%	9.7	338	3.00%	10.1	346	3.00%	10.4
19	Israel	219	4.27%	9.4	234	4.20%	9.8	246	4.20%	10.3
20	Austria	332	2.75%	9.1	350	2.75%	9.6	359	2.75%	9.9

		2010			2011			2012		
		GDP PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$	**GDP** PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$	**GDP** PPP Bil, US$	**R&D** as % GDP	**GERD** PPP Bil, US$
21	Turkey	960	0.85%	8.2	1,045	0.90%	9.4	1,080	0.90%	9.7
22	Singapore	292	2.52%	7.4	314	2.60%	8.2	331	2.65%	8.8
23	Belgium	394	1.96%	7.7	412	2.00%	8.2	423	2.03%	8.6
24	Finland	186	3.87%	7.2	196	3.83%	7.5	203	3.80%	7.7
25	Mexico	1,567	0.37%	5.8	1,663	0.38%	6.3	1,741	0.39%	6.8
26	Denmark	202	3.02%	6.1	209	3.05%	6.4	215	3.08%	6.6
27	Poland	721	0.68%	4.9	765	0.72%	5.5	796	0.72%	5.7
28	South Africa	524	0.93%	4.9	553	0.95%	5.3	579	0.95%	5.5
29	Norway	255	1.80%	4.6	265	1.85%	4.9	274	1.85%	5.1
30	Czech Republic	261	1.53%	4.0	272	1.55%	4.2	280	1.55%	4.3
31	Argentina	596	0.51%	3.0	658	0.58%	3.8	695	0.61%	4.2
32	Portugal	247	1.66%	4.1	247	1.65%	4.1	245	1.67%	4.1
33	Malaysia	414	0.64%	2.6	445	0.70%	3.1	472	0.70%	3.3
34	Ireland	172	1.77%	3.0	176	1.75%	3.1	181	1.75%	3.2
35	Hungary	188	1.15%	2.2	195	1.20%	2.3	201	1.20%	2.4
36	Indonesia	1,030	0.10%	1.0	1,120	0.15%	1.7	1,203	0.20%	2.4
37	Romania	254	0.59%	1.5	263	0.65%	1.7	275	0.66%	1.8
38	Saudi Arabia	622	0.10%	0.6	677	0.20%	1.4	708	0.25%	1.8
39	Greece	318	0.58%	1.8	314	0.55%	1.7	311	0.50%	1.6
40	New Zealand	118	1.18%	1.4	123	1.20%	1.5	129	1.22%	1.6

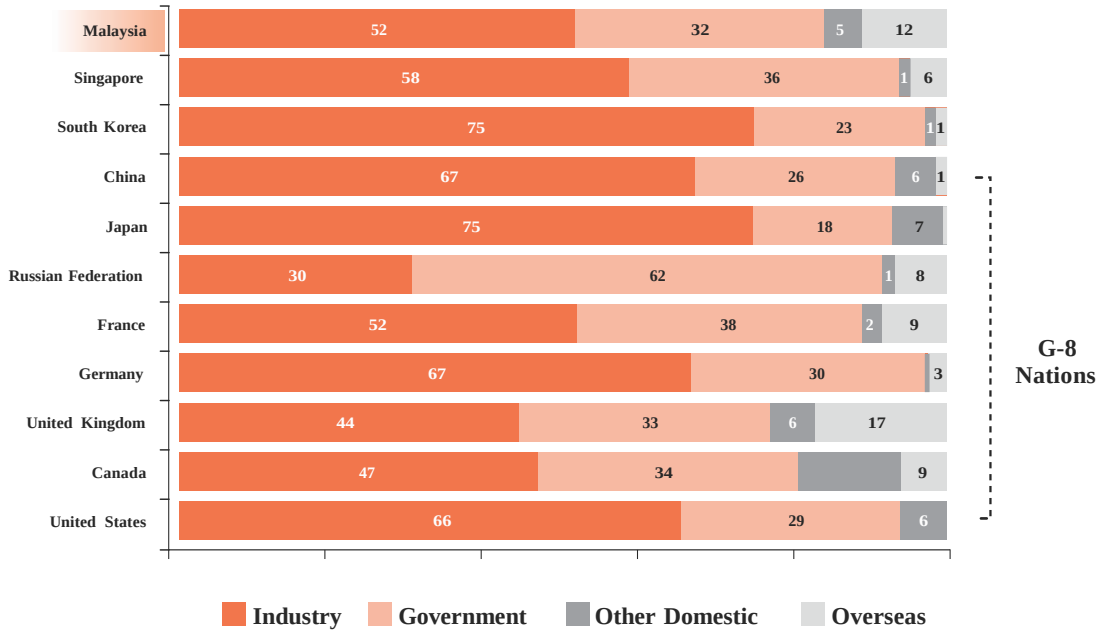


Figure 5. Source of research and development funding by country (6).

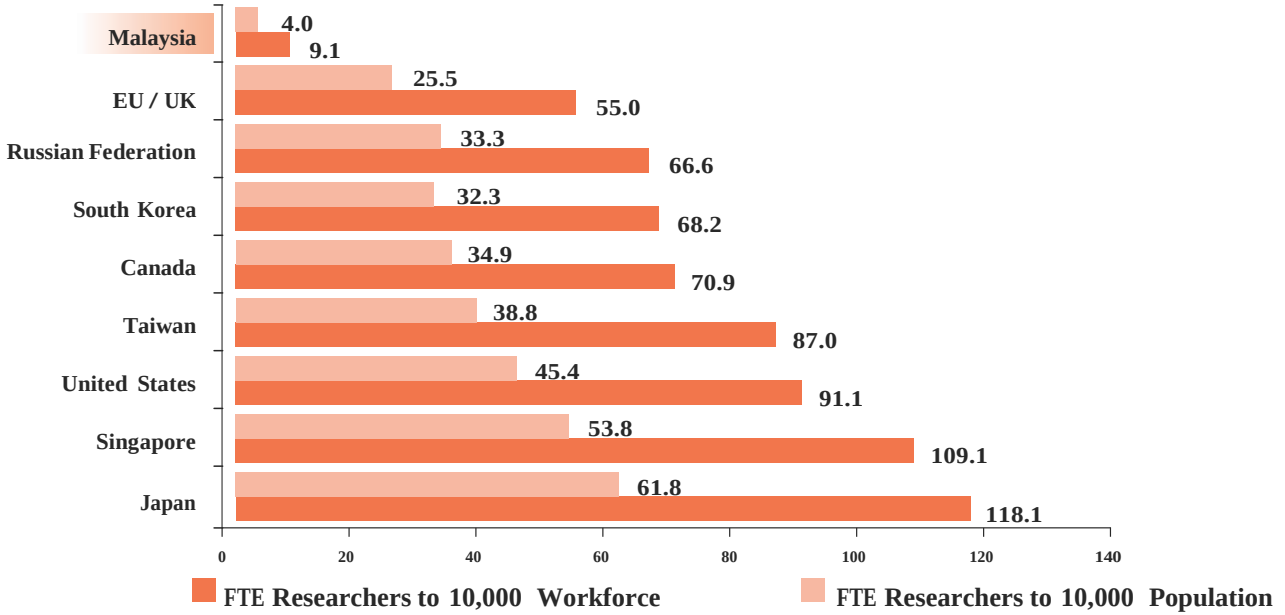
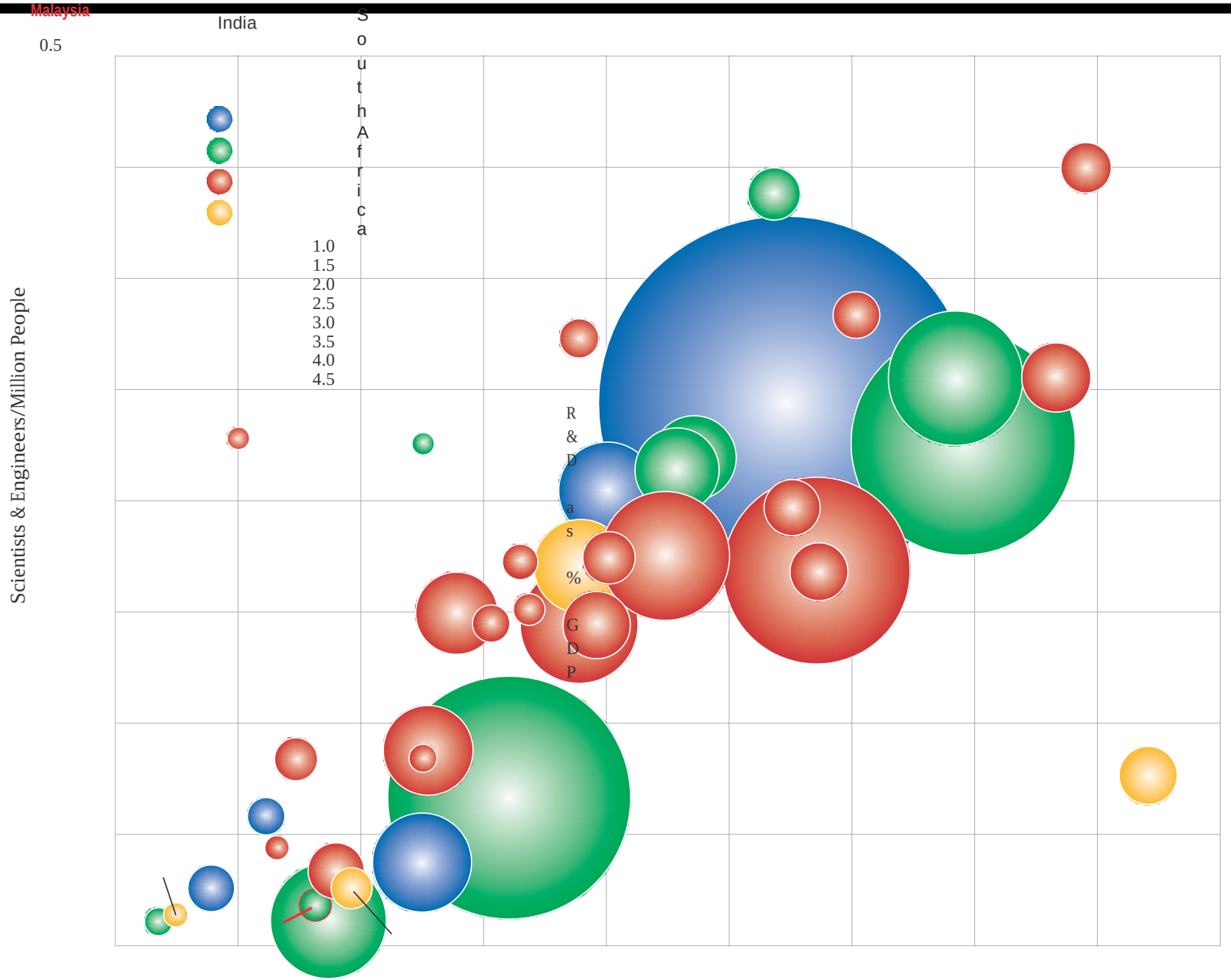


Figure 6 Full time equivalent researchers (FTE) by country (6).


8000
7000
6000
5000
4000
3000
2000
1000
0
Americas
Asia
Europe
Other
Finland
Singapore
Denmark
Norway
United States
South Korea
Sweden
Taiwan
New Zealand
Greece
Canada
Australia
Austria
Japan
Portugal
Belgium
Germany
France
Russia
Spain
Ireland
Switzerland
Netherlands
UK
Czech Republic
Poland
Italy
Israel
Argentina
Hungary
China
Turkey
Saudi Arabia
Mexico
Romania
Brazil
Indonesia


Malaysia
India
South Africa
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Scientists & Engineers/Million People
R & D as % GDP

Funding for stem cell research in Malaysia

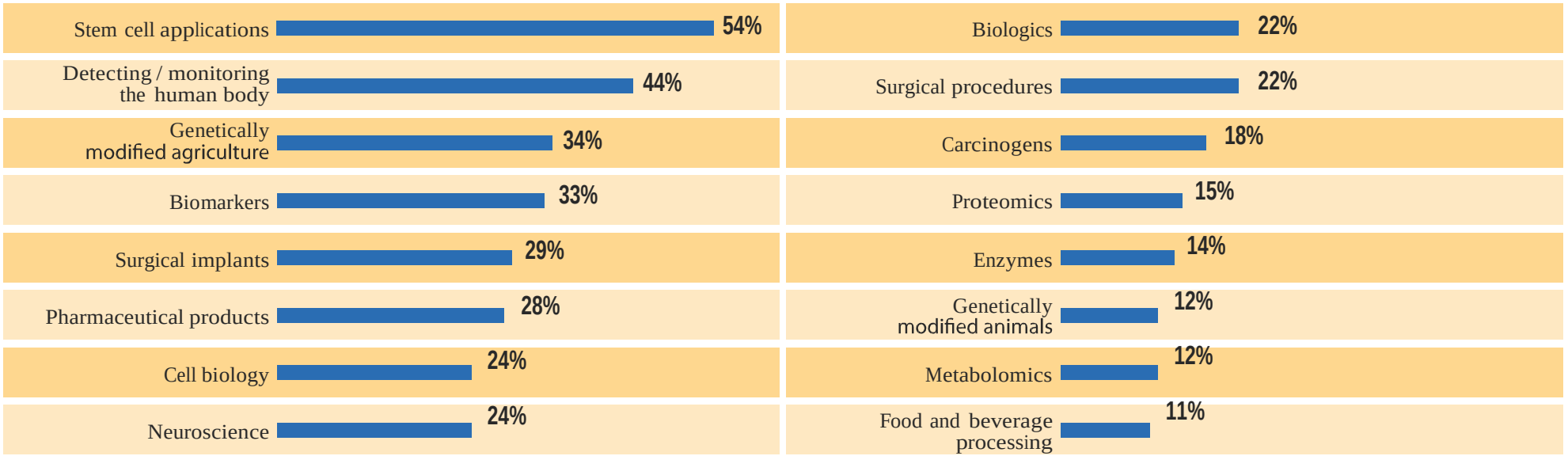


Figure 8. Predicted key life sciences research areas by 2014 (7).

Stem cell therapy is poised to be the major life science research area within the next five years, with a very high growth rate (CAGR of 23% from 2006-2010) (*Figure 8*) (8). Currently, orthopaedic applications of stem cell therapy are the most developed in Malaysia, but research on neurological, dental, and dermatological use is ongoing (*Figure 9*, Appendix *Table 4-I*). Tissue engineering is an emerging field where cultured cells are integrated with suitable biomaterial scaffolds to create artificial tissues. Locally, there is significant research interest in this area with a number of projects across the major universities (Appendix *Table 4-I*).

There are several local sources which can provide funding for stem cell research. The Ministry of Higher Education (MoHE) mainly provides grants for universities and other institutions of higher learning (*Table 2*). The Malaysian Biotechnology Corporation (BiotechCorp), Ministry of Science, Technology and Innovation (MOSTI), and Malaysian Technology Development Corporation (MTDC) also allow industry based researchers to apply (*Table 3*).

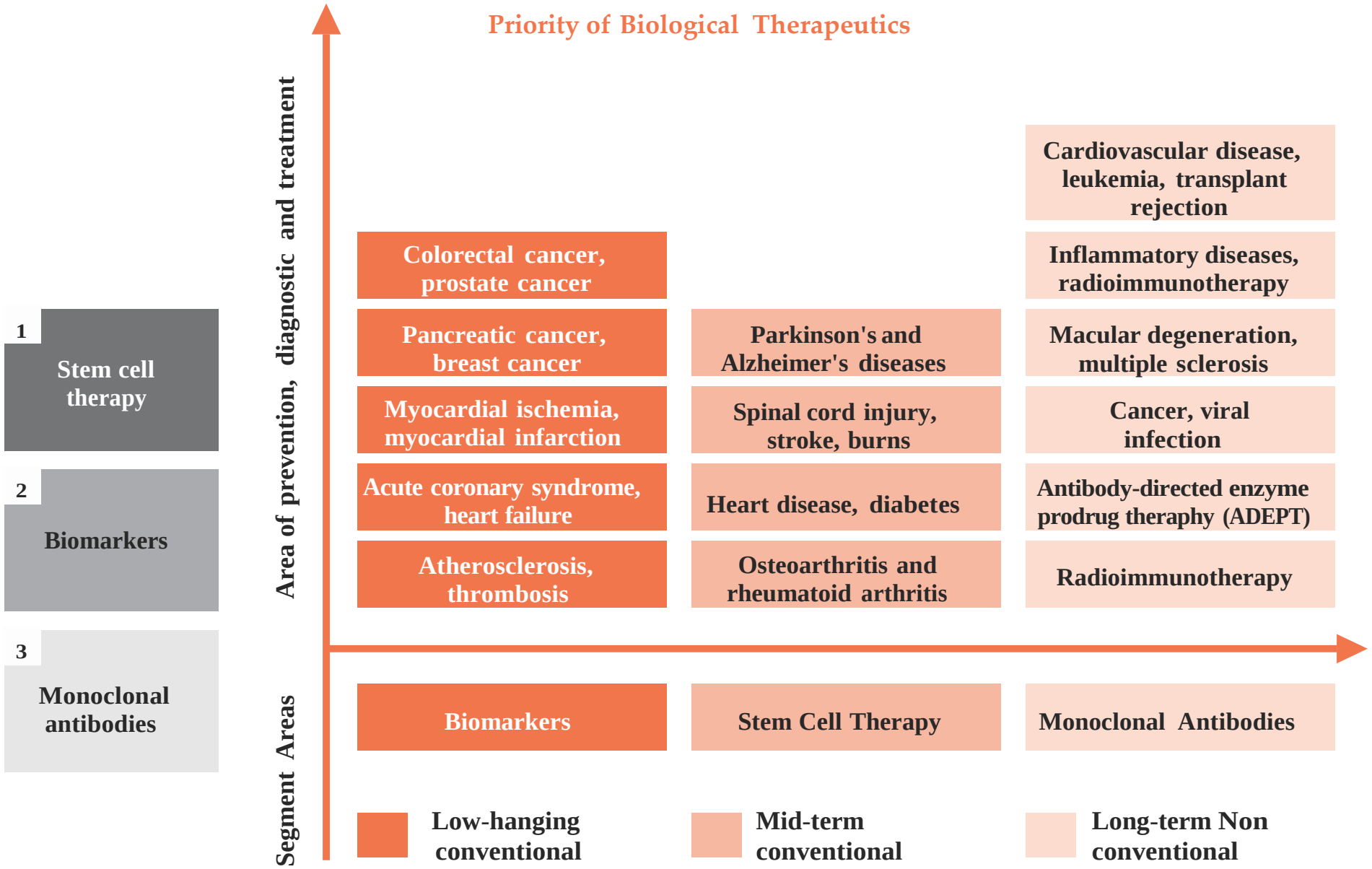


Figure 9. Priorities for life sciences research (8).

TABLE 2. AVAILABLE MOHE FUNDING SOURCES IN MALAYSIA.

Type of Fund	Details	Amount
Fundemental research grant scheme (FRGS)	Why and how Research that can produce new theories or concepts Discipline-based research Duration: 2–3 years Ceiling amount RM250K and maximum RM125K annually	Ceiling amount RM250K Maximum RM125K annually
Exploratory and experimental research grant scheme (ERGS)	What and where Problem-based research, inter-disciplinary (within institution) Expansion of ideas from the fundamental concept Findings can be further developed into applications Duration: 2–3 years Ceiling amount RM300k and maximum RM100k annually	Ceiling amount RM300K Maximum RM100K annually
Long-term research grant scheme (LRGS)	Fundamental research that needs more than 3 years Must be multi-institutional and multi-disciplinary Problem-based research Programme / cluster-based Duration: 3–5 years (at least 3 years) Ceiling amount RM15mil and maximum RM3mil annually	Ceiling amount RM15 million Maximum RM3 million annually
Prototype research grant scheme (PRGS)	Prototype development for pre-commercialisation Duration: 1–2 years Ceiling amount RM500k	Ceiling amount RM500K

* *MoHE - Ministry of Higher Education*

Available funding sources for healthcare biotechnology			
Type of Fund	**Details**	**Source**	**Amount**
Seed Fund	To fund seed or start-up costs in setting up biotech companies and to assist towards the development and commercialization of biotechnology projects and R&D findings of priority and core areas.	BiotechCorp	Up to RM2.5 million per company
Research & Development Matching Fund	To provide matching fund for R&D projects which can develop new or improved products and/or processes and/or technologies and lead to further development and commercialization within the Malaysia's Biotechnology Focus Areas.	BiotechCorp	Maximum of RM1.0 million per project
International Business Development Matching Fund	To promote the expansion of BioNexus Status Companies into the global market.	BiotechCorp	Maximum of RM1.25 million per project
Type A: Pre-commercialization	Pre-commercialization activities comprise development of pilot plant/up-scaling of laboratory prototype or development of commercial ready prototype/pre-clinical or clinical trials/field trials for demonstration and testing purposes and not for commercial production purposes.	MOSTI	Up to RM 5 million
Type B : IP Acquisition (Laboratory Scale)	Type B comprises acquisition of IP (academic/laboratory scale prototype) from overseas or local sources and must be further developed to pre-commercialization stage (Type A).	MOSTI	Up to RM 2 million

TABLE 3: AVAILABLE NON-MOHE FUNDING SOURCES IN MALAYSIA (8).

Available funding sources for healthcare biotechnology			
Type of Fund	**Details**	**Source**	**Amount**
INNOFUND — Enterprise Innovative Fund	To assist individuals / sole-proprietors, micro and small businesses/ enterprises to develop new or improve existing products, process or services with elements of innovation for commercialization.	MOSTI	Up to RM250,000
INNOFUND — Community Innovative Fund	To assist community groups to convert knowledge/idea into prodcts / processes / services that improves the quality of life of communities.	MOSTI	Up to RM500,000
CRDF 1	Feasibility Study on public sector R&D results for university/research institution's commercialization office.	MTDC	N/A – on case basis
CRDF 2	Commercialization of Public Sector R&D Results via University/Research Institution's Spin-Off Company.	MTDC	Up to RM 500,000
CRDF 3	Commercialization of Public Sector R&D Results via Start-up Company	MTDC	Up to RM 500,000
CRDF 4	Commercial Production of Any Locally Generated R&D Results by SME	MTDC	Up to RM 4 million
Technology acquisition fund (TAF)	Technology Acquisition Fund (TAF) provides partial grant to further promote efforts by the private sector to enhance their technology level and production processes.	MTDC	Up to RM 2 million
Science and technology research grant	To help in research activities	Malaysia Toray Science Foundation (MTSF)	Up to RM 300,000

** BiotechCorp - Malaysian Biotechnology Corporation; MoHE - Ministry of Higher Education; MOSTI - Ministry of Science, Technology and Innovation; MTDC - Malaysian Technology Development Corporation*

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TCM is used in Malaysia by 50%–80% of the population
The predominant forms of TCM locally are biologically based therapies such as herbal medicine
TCM use rises with disability, although to a lesser extent than Western medicine
The role of TCM in stem cell therapy is primarily as an adjuvant treatment
Published research in this field is currently sparse
Asian countries have a strong tradition of using herbs for anti-ageing
TCM practice in Malaysia is monitored by the TCM division of the Ministry of Health, and supported by professional bodies

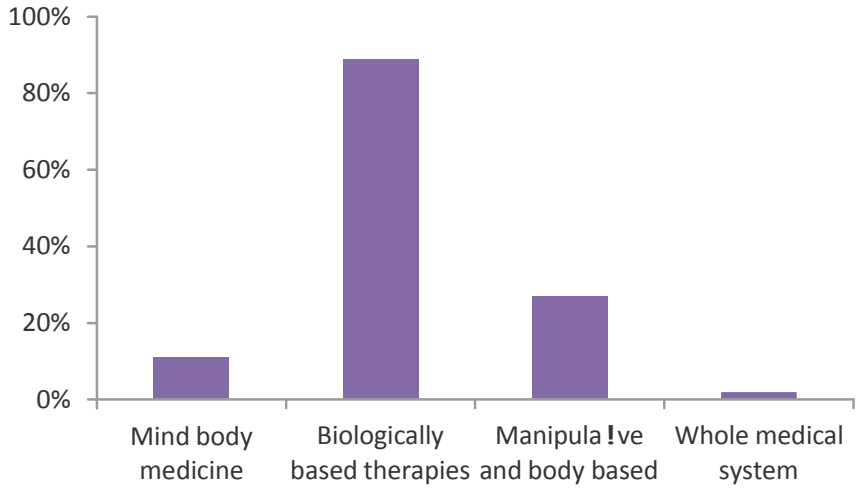

Figure 1. *Prevalence of TCM modalities in Malaysia for treatment (1).*

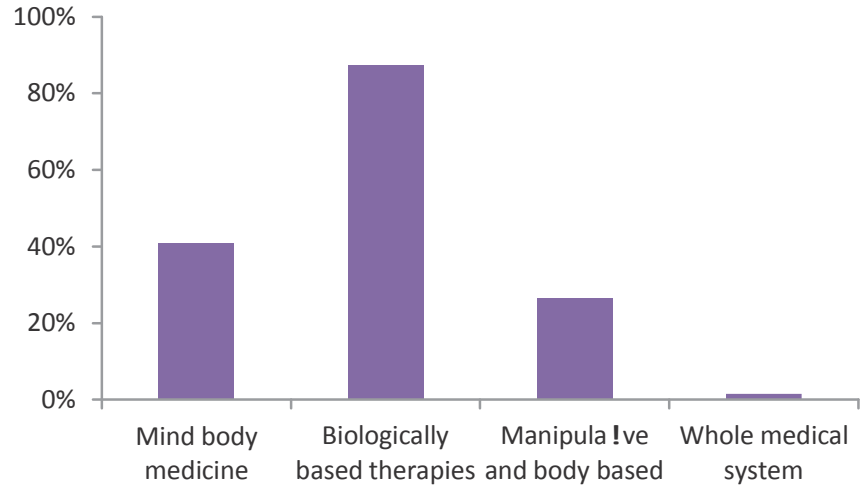

Figure 2. *Prevalence of TCM modalities in Malaysia for health maintenance (1).*

TCM has been defined by the World Health Organization (WHO) as the sum total of the knowledge, skills, and practices based on the theories, beliefs and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health as well as prevention, diagnosis, improvement, or treatment of physical and mental illness. According to the WHO, approximately 65% and 50-80% of the population of developed and developing countries respectively use TCM. The WHO has also recognised the importance of TCM in health promotion for a large segment of the population, especially in developing countries.

TCM is broadly classified into four categories: mind-body medicine, biologically based therapies, manipulative and body based treatments, and whole medical systems (*Table 1*). It can be used both for treatment of disease and maintenance of good health. Usage of TCM in Malaysia is widespread, and biologically based therapies, particularly herbal medicine, account for most of the TCM used locally (*Figure 1–2, Table 2–3*).

The overall prevalence of TCM usage in Malaysia is between 50-80%, which is similar to the WHO figures for other developing countries (1). Usage of TCM increases with the degree of disability, although not to the same extent as Western medicine (*Figure 3*).

TABLE 1: PREVALENCE OF TCM MODALITIES IN MALAYSIA FOR TREATMENT AND HEALTH MAINTENANCE (2)

Mind-body medicine. Mind-body medicine uses a variety of techniques designed to enhance the mind's capacity to affect bodily function and symptoms. Some techniques that were considered TCM in the past have become mainstream (for example, patient support groups and cognitive- behavioural therapy). Other mind-body techniques are still considered TCM, including meditation, prayer, mental healing, and therapies that use creative outlets such as art, music, or dance.
Biologically based therapies. Biologically based therapies in TCM use substances found in nature, such as herbs, foods, and vitamins. Some examples include dietary supplements, herbal products, and the use of other so-called "natural" but as yet scientifically unproven therapies (for example, using shark cartilage to treat cancer).
Manipulative and body-based methods. Manipulative and body-based methods in TCM are based on manipulation and/or movement of one or more parts of the body. Some examples include chiropractic or osteopathic manipulation, and massage.
Whole medical systems. Whole medical systems are built upon complete systems of theory and practice. Often, these systems have evolved apart from and earlier than the conventional medical approach used in the United States. Examples of alternative medical systems that have developed in Western cultures include homeopathic medicine and naturopathic medicine. Examples of systems that have developed in non-Western cultures include traditional Chinese medicine and Ayurveda.

TABLE 2. PREVALENCE OF TCM MODALITIES IN MALAYSIA FOR TREATMENT, BY AGE, GENDER, MARITAL STATUS, EDUCATION LEVEL, WORKING STATUS, AND ETHNIC GROUP (1)

Characteristic		Mind body medicine (95% CI)	Biologically based therapies (95% CI)	Manipulative and body based (95% CI)	Whole medical system (95% CI)
Age	0—9	15.3%(12.3,19.0)	87.6%(84.2,90.3)	21.7%(18.3,25.6)	0.6%(0.3,1.5)
	10—19	11.5%(9.2,14.2)	89.2%(86.591.4)	20.9%(17.7,24.4)	0.6%(0.2,1.8)
	20—29	10.0%(7.8,12.7)	86.8%(83.7,89.3)	28.3%(24.5,32.5)	1.7%(1.0,3.2)
	30—39	8.7%(6.5,11.4)	89.4%(86.4,91.8)	34.6%(30.7,38.8)	1.9%(1.1,3.5)
	40—49	10.5%(8.3,13.4)	89.0%(86.1,91.4)	30.1%(26.2,34.4)	2.8%(1.7,4.5)
	50—59	9.0%(6.4,12.5)	92.1%(88.9,94.5)	25.8%(21.4,30.8)	4.2%(2.6,6.7)
	60—69	11.4%(7.9,16.2)	92.4%(88.6,95.0)	28.3%(22.7,34.7)	1.9%(0.8,4.4)
	70—79	8.4%(4.4,15.5)	83.5%(74.4,89.7)	30.9%(22.5,40.8)	5.6%(2.5,11.9)
	80 and above	22.0%(15.5,38.6)	95.1%(82.0,98.8)	22.9%(12.1,39.2)	2.8%(0.4,17.7)
Sex	Male	10.9%(9.4,12.6)	88.0%(86.4,89.5)	26.6%(24.5,28.9)	2.1%(1.5,3.0)
	Female	11.2%(9.7,12.9)	89.8%(88.2,91.1)	27.3%(25.3,29.4)	1.7%(1.2,2.4)
Marital status	Single	12.7%(10.9,14.7)	87.7%(85.8,89.3)	22.7%(20.4,25.1)	1.3%(0.8,2.0)
	Married	9.5%(8.2,11.0)	89.9%(88.2,91.1)	30.8%(28.5,33.1)	2.4%(1.8,3.2)
	Divorcee/widow/widower	12.0%(8.2,17.1)	91.5%(86.8,94.6)	31.7%(25.5,38.5)	3.3%(1.5,7.0)
	Cohabit	—	78.0%(24.1,97.5)	22.0%(2.5,75.9)	—
Education level	No formal schooling	14.3%(11.4,17.8)	91.5%(88.9,93.6)	25.5%(21.9,29.4)	2.0%(1.1,3.6)
	Primary	10.5%(8.7,12.5)	89.4%(87.2,91.2)	26.4%(23.6,29.4)	1.8%(1.1,2.8)
	Lower secondary	10.7%(8.6,13.4)	86.8%(84.1,89.0)	27.4%(24.0,31.0)	1.5%(0.8,2.6)
	Upper secondary	8.5%(6.7,10.6)	89.7%(87.4,91.7)	28.7%(25.6,32.0)	1.8%(1.1,2.9)
	College/university	10.4%(7.4,14.4)	86.9%(82.1,90.6)	30.5%(25.3,36.3)	4.6%(2.7,7.6)
Working status	Housewife	9.7%(7.7,12.3)	91.5%(88.6,93.0)	31.8%(28.3,35.5)	1.9%(1.1,3.3)
	Schooling	12.0%(9.8,14.6)	89.4%(86.9,91.5)	21.7%(18.5,25.3)	0.8%(0.4,1.8)
	Government	8.1%(5.2,12.3)	90.0%(85.4,93.3)	36.0%(30.0,42.4)	1.9%(0.8,4.4)
	Private	9.1%(7.3,11.4)	88.1%(85.6,90.2)	27.3%(24.2,30.7)	2.4%(1.6,3.7)
	Self employment	10.4%(8.1,13.3)	89.0%(86.0,91.5)	31.1%(27.2,35.2)	3.3%(2.0,5.2)
	Pensioner	14.7%(8.9,23.3)	85.8%(76.6,91.7)	21.1%(13.1,31.6)	3.0%(1.0,9.0)
	Not working/schooling	15.8%(11.4,21.5)	88.5%(84.1,91.8)	22.4%(17.8,27.9)	1.4%(0.5,3.6)
Ethnic group	Malay	13.1%(11.5,14.8)	86.4%(84.8,87.9)	31.0%(28.9,33.3)	0.8%(0.5,1.2)
	Chinese	5.1%(3.1,8.2)	92.4%(89.9,94.4)	15.7%(12.9,19.1)	6.6%(4.9,8.8)
	Indian	5.9%(2.8,12.2)	92.0%(87.1,95.1)	18.6%(13.5,24.9)	2.8%(0.8,10.0)
	Bumiputra Sabah	11.4%(7.7,16.7)	97.3%(94.3,98.7)	28.2%(21.6,35.8)	1.1%(0.3,3.2)
	Bumiputra Sarawak	11.0%(7.0,16.8)	91.2%(86.3,94.5)	22.9%(17.8,29.0)	0.8%(0.2,3.3)
	Orang Asli	11.7%(7.1,18.6)	76.4%(56.1,89.2)	64.9%(38.2,84.7)	0.6%(0.1,3.9)

Characteristic		Mind body medicine (95% CI)	Biologically based therapies (95% CI)	Manipulative and body based (95% CI)	Whole medical system (95% CI)
Age	0–9	31.7%(24.6–39.7)	89.9%(86.5–92.6)	11.9%(8.6–16.4)	3.0%(1.4–6.4)
	10–19	58.8%(53.1–64.3)	80.5%(76.5–84.0)	11.5%(8.3–15.7)	1.5%(0.5–4.5)
	20–29	39.4%(33.6–45.6)	89.2%(86.3–91.5)	29.1%(25.0–33.5)	1.2%(0.5–3.0)
	30–39	39.4%(33.8–45.3)	85.6%(82.5–88.2)	34.3%(30.5–38.4)	.6%(0.8–3.5)
	40–49	31.7%(26.1–37.9)	92.4%(89.8–94.4)	37.5%(33.2–42.0)	1.1%(0.4–2.7
	50–59	39.1%(32.2–46.5)	88.8%(84.9–91.8)	9.4%(24.4–34.9)	0.6%(0.1–2.3)
	60–69	44.6%(35.7–53.9)	83.1%(76.7–88.0)	26.0%(20.0–32.9)	1.6%(0.5–4.8)
	70–79	31.6%(20.5–45.3)	83.1%(83.9–96.1)	24.4%(15.8–35.7)	2.6%(0.6–9.7)
	80 and above	39.8%(19.4–64.4)	75.9%(55.6–88.8)	41.6%(24.1–61.5)	–
Sex	Male	46.1%(42.5–49.8)	87.1%(85.1–88.8)	12.4%(10.6–14.5)	1.8%(1.1–2.8)
	Female	35.9%(32.6–39.4)	87.5%(85.8–89.0)	37.2%(34.7–39.8)	1.4%(0.9–2.2)
Marital status	Single	45.7%(41.5–50.0)	86.5%(84.2–88.4)	12.9%(10.7–15.4)	1.8%(1.0–3.1)
	Married	38.1%(34.7–41.5)	88.0%(86.3–89.5)	33.7%(31.5–36.1)	1.4%(0.9–2.2)
	Divorcee/widow/ widower	29.9%(21.8–39.6)	88.8%(82.4–93.1)	48.1%(40.4–55.8)	–
	Cohabit	100%	100%	–	–
Education level	No formal schooling	35.3%(28.8–42.5)	87.5%(83.3–90.8)	23.9%(19.4–29.2)	1.3%(0.6–2.8)
	Primary	39.5%(34.9–44.3)	85.8%(83.3–88.0)	25.9%(22.8–29.3)	0.7%(0.3–1.8)
	Lower secondary	41.8%(36.6–47.2)	86.3%(85.4–90.7)	28.8%(25.1–32.8)	1.4%(0.5–3.6)
	Upper secondary	48.2%(43.2–53.2)	85.8%(83.3–88.0)	28.7%(25.4–32.2)	1.2%(0.6–2.3)
	College/university	44.9%(37.4–52.6)	89.7%(85.8–92.7)	28.0%(22.5–34.3)	3.1%(1.4–6.9)
Working status	Housewife	30.8%(25.8–36.4)	87.2%(84.1–89.7)	49.7%(45.7–53.8)	1.1%(0.5–2.4)
	Schooling	53.4%(47.5–59.3)	83.2%(79.4–86.4)	9.4%(6.6–13.2)	1.4%(0.5–3.8)
	Government	40.9%(33.1–49.1)	86.8%(81.9–90.5)	35.7%(29.8–42.0)	2.8%(1.2–6.6)
	Private	41.4%(36.1–46.8)	89.9%(87.6–91.8)	21.5%(18.4–24.9)	1.0%(0.4–2.2)
	Self employment	38.5%(32.9–44.4)	88.4%(85.1–91.0)	27.9%(23.9–32.3)	1.3%(0.6–2.8)
	Pensioner	57.4%(43.7–70.1)	85.7%(76.0–91.9)	16.4%(8.9–28.4)	1.3%(0.2–8.7)
	Not working/ schooling	39.2%(29.7–49.6)	85.0%(79.0–89.4)	18.0%(12.3–25.5)	1.3%(0.3–4.1)
Ethnic group	Malay	38.6%(35.4–41.9)	84.5%(82.6–86.2)	32.4%(30.1–34.8)	1.7%(1.0–2.7)
	Chinese	51.8%(44.4–59.1)	92.4%(89.3–94.7)	10.9%(7.9–14.9)	1.8%(0.8–3.6)
	Indian	58.8%(48.7–68.3)	89.5%(84.5–94.7)	18.1%(12.8–24.9)	0.5%(0.1–3.4)
	Bumiputra Sabah	35.9%(24.6–48.9)	89.7%(83.3–93.8)	21.0%(15.3–27.9)	1.7%(0.4–6.7)
	Bumiputra Sarawak	26.0%(15.9–39.5)	86.7%(79.1–91.8)	25.0%(17.2–34.9)	1.6%(0.4–6.0)
	Orang Asli	42.3%(26.4–59.9)	93.2%(88.4–96.1)	27.3%(19.2–37.2)	–

TABLE 3 PREVALENCE OF TCM MODALITIES IN MALAYSIA FOR HEALTH MAINTENANCE, BY AGE, GENDER, MARITAL STATUS, EDUCATION LEVEL, WORKING STATUS, AND ETHNIC GROUP (1)

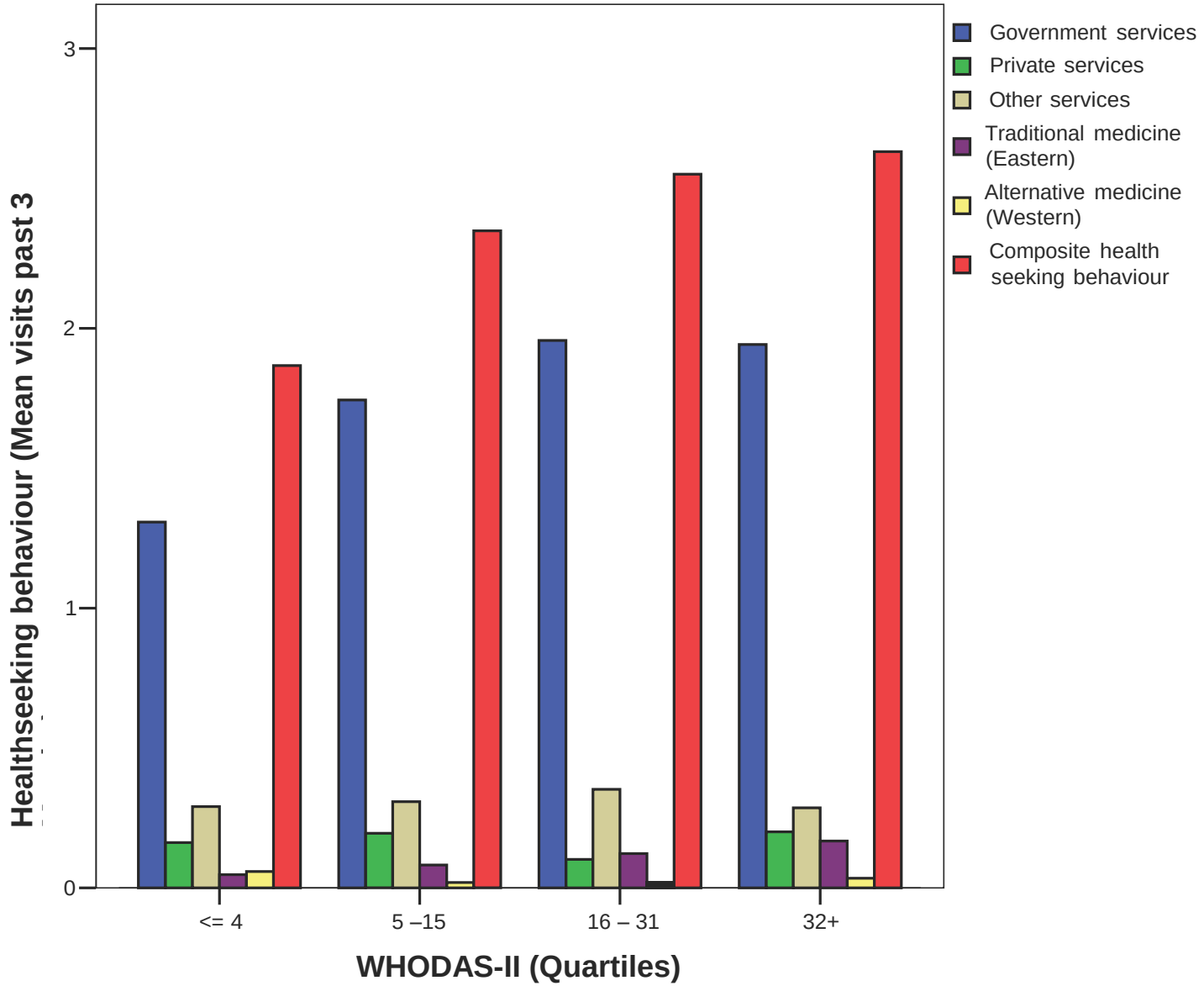

Figure 3. Healthcare usage by older Malaysians according to degree of disability.

** Combined MHQoL National Data 2006, Wellness National Data 2009 - Institute of Gerontology, UPM.*

The Role of TCM in Regenerative Medicine

The goal of regenerative medicine is to repair or replace damaged tissue and restore it to a state as close as possible to the original. Stem cell therapy is one of the mainstays of regenerative medicine, and works best when combined with new biomaterials and adjuvant treatments. These adjuvant treatments can consist of medicines or nutritional supplements, which may include TCM biologically based therapies (3).

Small molecule signalling compounds have been shown to regulate the differentiation of cells, even to the extent of inducing primitive stem cells to form out of existing cell types such as skin (4). This approach potentially allows the production of large populations of homogenous cell types for stem cell therapy, without the ethical issues of using embryonic cells or the medical risks of repeatedly harvesting autologous stem cells from patients. Another promising approach is the development of therapeutic agents which can stimulate endogenous cells to regenerate (5).

There is very little information on TCM use in regenerative medicine and stem cell therapy currently. The few published articles discuss the activity of various Chinese herbal preparations in promoting the proliferation or differentiation of mesenchymal stem cells. The diseases studied include neurodegenerative disorders, cardiovascular disease, and osteoporosis (6, 7).

Ageing is a natural process in all living organisms in which there is
a steady accumulation of damage to cells and tissues. While the body's repair processes are fairly efficient, they are not perfect and with time the accumulated damage leads to impairment of function and development of disability. Stem cells play an important role in these repair mechanisms, replenishing damaged cells throughout the body and maintaining normal turnover in tissues (8). Any substance which can augment the function or activity of these stem cells can potentially improve the efficiency of the body's repair mechanisms, thus exerting an anti-ageing effect.

TCM in Asian countries have a strong tradition of utilising herbal preparations for their anti-ageing properties. According to these traditions, ageing is viewed as a progressive decline of "vital energy" in the body, leading to a deterioration of function and development of disease. This "vital energy" is believed to consist of both physical and mental energy, and possesses multiple functions in the areas of growth, daily activities, reproduction, cognition, and disease prevention.

The herbs regarded as having anti-ageing effects usually share some common properties:

(1) "Tonifying" — able to boost the level of "vital energy" in the body

(2) "Multi-staged"—provide essential nutrients in health, and treat diseases when ill; and
(3) "Multi-targeted" — effective in the treatment of multiple diseases

The pharmacological properties ascribed to these herbs include revitalizing action, anti-infective, anti-tumour, anti-stress, anti-oxidant, mind-boosting, rejuvenating, improved protein activity and synthesis, immune-stimulating, anti-inflammatory, and reduction of free radicals. In their role as anti-ageing therapy, they can be used for treatment of coronary disease, sleep disorders, cause dilatation of blood vessels, skeletal muscle relaxation, have anaesthetic properties, prevent radiation induced DNA damage, and alleviate depression and anxiety associated with ageing.

Some of the herbs believed to have anti-ageing properties are: *Aloe vera, Withania somnifera, Bacopa monnieri, Uncaria tomentosa, Cinnamomum zeylanicum, Echinacea purpurea, Phyllanthus emblica, Ginkgo biloba, Panax ginseng, Camellia oleifera, Crataegus monogyma, Aesculus hippocastanum, Piper methysticum, Garcinia mangostana, Pinus pinaster, Silybum marianum, Passiflora incarmata, Prunus africanum, Serenoa repens, Hypericum perforatum, Urtica dioica, Curcuma longa, Valeriana officinalis*, and Shilajit (9).

The active compounds in these herbs which are believed to mediate their anti-ageing properties are: alpha-mangostin and gamma-mangostin, silybin, hypericin, hyperforin, curcumin, gamma-linolenic acid, diindolylmethane, bromocriptine, choline alfoscerate, levodopa, resveratrol, and vinpocetine (*Figure 4*).

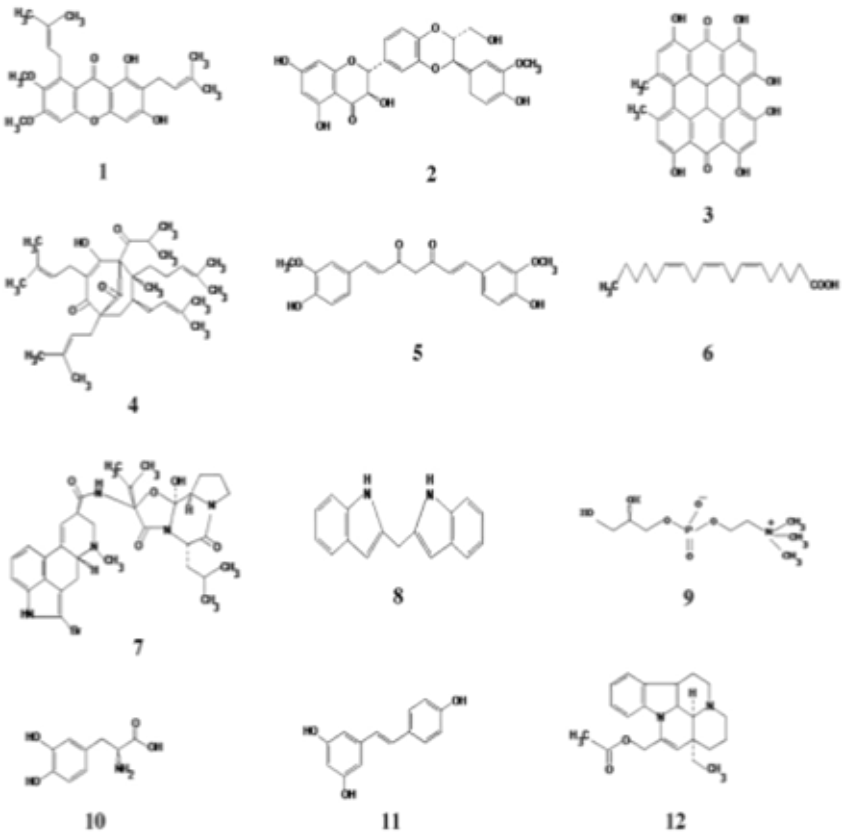

Figure 4. Active compounds in herbs with potentially anti-ageing properties (9).

** (1) alpha-mangostin and gamma-mangostin, (2) silybin, (3) hypericin, (4) hyperforin, (5) curcumin, (6) gamma-linolenic acid, (7) diindolylmethane, (8) bromocriptine, (9) choline alfoscerate, (10) levodopa, (11) resveratrol, and (12) vinpocetine.*

The Practice of TCM in Malaysia

TCM in Malaysia is broadly classified into six categories: Chinese traditional medicine, Malay traditional medicine, Indian traditional medicine, homeopathy, complementary medicine and Islamic medical practice. TCM was first registered in Malaysia in 1992, followed by the development of the National Policy on TCM in 2001, and the formation of the TCM Division of the Ministry of Health in 2004 (10, 11). The TCM Division was formed with the aim of integrating TCM into the Malaysian healthcare system, by ensuring the quality of products and promoting safe use of TCM practices.

By 2010, there were eight public hospitals which offer an in-house TCM service, being Hospital Putrajaya, Hospital Kepala Batas, Hospital Sultan Ismail, Hospital Sultanah Nur Zahirah, Hospital Umum Sarawak, Duchess of Kent Hospital, Hospital Port Dickson, and Hospital Sultanah Bahiyah.

Eight professional bodies for TCM are recognised, which are the Gabungan Pertubuhan Pengamal Perubatan Melayu Malaysia (GAPERA), the Federation of Chinese Physicians and Medicine-Dealers Association of Malaysia (FCPMDAM), the Federation of Chinese Physicians and Acupuncturists Association of Malaysia (FCPAAM), the Malaysian Chinese Medical Associations (MCMA), the Malaysian Association of Traditional Indian Medicine (PEPTIM), the Malaysian Homeopathic Medical Council (MPHM), the Federation of Complementary and Natural Medical Associations Malaysia (FCNMAM), and the Persatuan Kebajikan dan Pengubatan Islam Malaysia (Darussyifa') (Table 4). In addition, a number of TCM training centres were set up by these associations: FCPAAM (8), FCPMDAM (8), MCMA (2), and MPHM (8).

TABLE 4: MEMBERSHIP OF SELECTED TCM PROFESSIONAL BODIES IN MALAYSIA (11)

Professional body	Number of practitioners
FCPMDAM	3035
FCPAAM	1048
PEPTIM	50
MPHM	691

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Evidence on Ageing, Chronic Disease, and Disability Trends
Cardiovascular diseases and visual-hearing impairments have the greatest impact on Disability-Adjusted Life Years (DALY), while dementia has a relatively small effect
Musculoskeletal conditions have a moderate impact on DALY, but research in this field is most developed locally
Recommendation: funding (in decreasing order of priority) should be given to stem cell research on cardiovascular diseases, visual-hearing impairment, musculoskeletal conditions, and dementia

Ethical, Religious, and Regulatory Framework
There are significant ethical issues surrounding embryonic stem cell research, therapeutic, and reproductive cloning
Non-embryonic stem cell alternatives are emerging and these will eventually replace embryonic stem cells for clinical therapy
This means that any product or patent for clinical use of embryonic stem cells will lose their value with time
<u>Recommendation</u>: government funding for clinical and commercial applications of embryonic stem cells should be diverted to finding non-embryonic alternatives with the same functionality

Ethical, Religious, and Regulatory Framework
Some basic embryonic stem cell research may be necessary to understand cellular processes
Recommendation: government funding for basic embryonic stem cell research should be limited to the use of pre-existing embryonic stem cell lines
The applications for therapeutic cloning are mainly clinical, with similar ethical issues as for embryonic stem cells
Recommendation: government funding for therapeutic cloning should be withheld

Ethical, Religious, and Regulatory Framework
There is a diversity of opinion on the ethical issues regarding embryonic stem cells and therapeutic cloning
<u>Recommendation</u>: there should not be any regulatory barrier for conducting embryonic stem cell research and therapeutic cloning
Public opinion is uniformly against reproductive cloning
<u>Recommendation</u>: reproductive cloning should be banned

Policy and Funding for Stem Cell Research
Research funding and manpower for Malaysia are relatively good for a developing nation
To achieve developed nation status by 2020, we will still need substantial investment on a sustained basis, especially in manpower
Recommendation: government funding for stem cell research in 2012 should be RM32 million
Recommendation: attract Malaysian researchers currently abroad to return, and adjust the immigration policy to draw foreign researchers to Malaysia, with a target of bringing in 650-1500 researchers across all fields for 2012

TCM, Regenerative Medicine, and Ageing
There is very little research on TCM in stem cell therapy
Malaysia has competitive advantages in this area with multiple TCM traditions, established stem cell research, and little competition from developed countries
Recommendation: research on TCM in stem cell therapy should be given priority in funding

Overall Recommendation: set up a Stem Cell Institute to coordinate research funding and direction in this area

Evidence on Ageing, Chronic Disease, and Disability Trends

TABLE 1: AGE-STANDARDISED DISABILITY-ADJUSTED LIFE YEARS (DALY) FOR SELECTED DISEASE GROUPS IN 2004 (1)

	United states	Australia	Singapore	Malaysia
Dementia	260	269	155	166
Musculoskeletal	447	410	583	598
Visual-hearing	780	480	1075	2021
Cardiovascular*	1899	1170	1767	2865

** total cardiovascular and diabetes mellitus*

The Disability-Adjusted Life Year (DALY) is a measure of disease burden expressed as the cumulative number of years lost due to ill health, disability, or early death. A crucial aspect of DALY is that of social weighting in which the value of a particular year of life depends on how much society's return on investment is impacted should that year be lost. This means that greatest value is place on the life of young adults, while that of older people and young children have least value. This is because society has invested very little in educating young children, while older people have already returned to society most of its investment.

Hence, cardiovascular diseases and visual-hearing impairment have the highest DALY among the four disease groups listed in Table 1. This is in spite of the fact that dementia and musculoskeletal conditions account for most of the disability among older people (*Chapter 1; Figure 7*), because these conditions have a later onset and result in a smaller impact on DALY.

From this we can see that priority should be given to stem cell research on cardiovascular diseases and visual-hearing impairments as these have the largest benefits to society in terms of productivity. Funding for musculoskeletal conditions should also be continued given that this kind of research is most developed in Malaysia (*Appendix Table 4-I*). As dementia has the least impact on DALY, funding priority for this condition should be lowest among the top four conditions, in spite of the large disability burden among the elderly. Furthermore, stem cell research on dementia will take a long time to bear results given that there are technical difficulties in even isolating adult neural stem cells.

Ethical, Religious, and Regulatory Framework

From Chapter 3, it is apparent that a significant segment of the population has ethical concerns about some forms of stem cell therapy, specifically embryonic stem cell research, therapeutic, and reproductive cloning. The main issue is that these techniques require the destruction of an embryo in order to produce the required cell lines.

Currently, embryonic stem cells have some advantages over adult stem cells in certain applications, but with technological advances these advantages are gradually disappearing. The discovery of induced pluripotent stem cells, which are adult stem cells that have been chemically reprogrammed to have pluripotent characteristics, gives many of the advantages of embryonic stem cells without the ethical controversy (2).

With time, the capabilities of non-embryonic and embryonic stem cells will eventually converge. However, the ethical issues surrounding embryonic stem cells will remain for the foreseeable future. This means that any patents or products that are produced using embryonic stem cells will eventually lose their value once non-embryonic alternatives become available.

From Chapter 4, we see that the resources available for research in Malaysia are limited, and it makes sense to divert funding away from commercial and clinical applications of embryonic stem cells to research that produces non-embryonic alternatives with the same functionality. This will ensure that our country maximises its return on research investment to produce products with a longer commercial lifespan.

However, some research on embryonic stem cells may still be necessary to refine the understanding of basic cellular processes involved in pleuripotency. It is likely though that the diversity of currently available embryonic cell lines will allow for this to be done without taking the step of creating a new cell line that entails the destruction of an embryo, and its accompanying ethical problems. For existing embryonic cell lines, the ethical burden has already been borne by the original researchers, and there is very little ethical difficulty in utilising these cell lines provided no new destruction of embryos takes place.

This means that basic research on embryonic stem cells should still receive funding, provided that these cell lines are already pre-existing. In practice, this will require a cut-off date to be set after which newer embryonic cell lines will be deemed to be unacceptable for this purpose. Exceptions to this policy can still be made on a case by case basis, provided strong justification can be found that all other alternatives have been examined and seen to be unsuitable.

For embryonic stem cell research that is commercially funded, there should not be any regulatory barrier other than going through an established ethics review board. The fact that there is a diversity of opinion on this issue means that the regulatory authorities have much less justification to impose restrictions based on any single worldview.

The situation with therapeutic cloning is clearer in that its main purpose is to produce cell lines that are tailored to an individual. This means that the application of this technology is essentially clinical, and using the same reasoning as for embryonic stem cell research, therapeutic cloning should not be funded using public money.

For reproductive cloning, the consensus among most ethical and religious authorities is that it is morally wrong. This is a situation where the regulatory authorities have good justification to ban the practice as public opinion is fairly uniform on this.

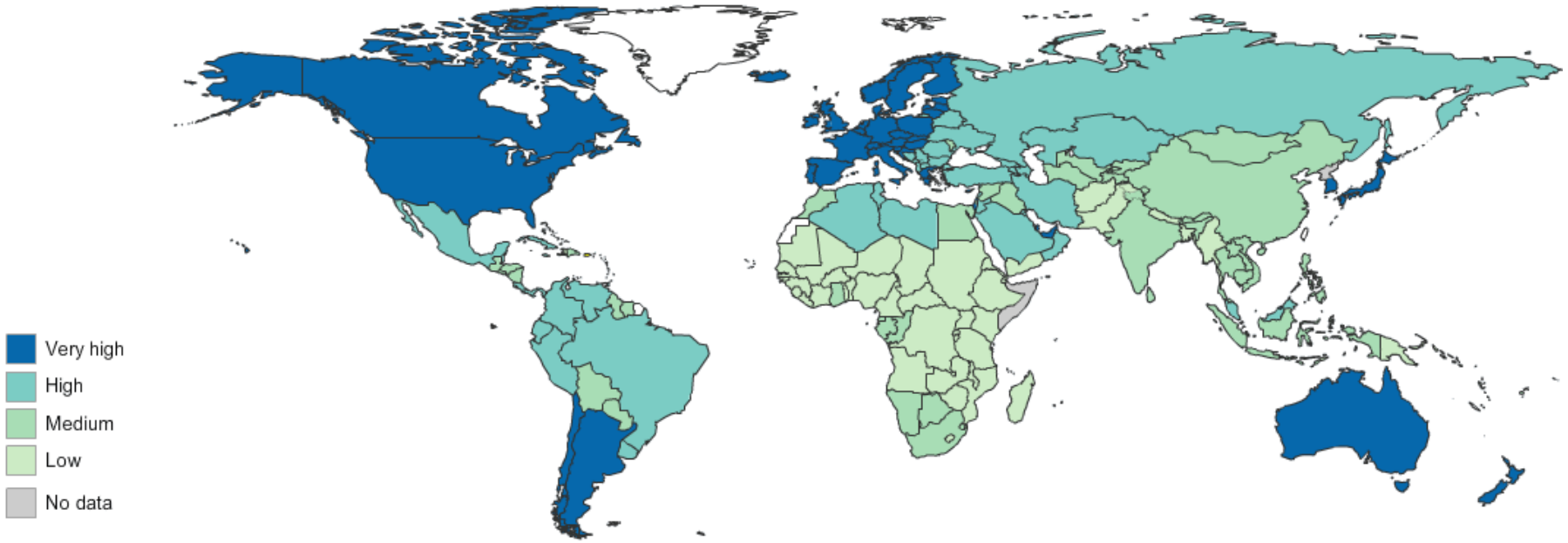


Figure 1. World map by quartiles of Human Development Index (HDI) in 2011 (4).

** Developed countries are those with very high HDI (top quartile)*

This section of the report takes the form of a modified Gap Analysis to make its recommendations based on Malaysia's intention to become a developed nation by 2020. There are however significant uncertainties when integrating data from varied sources, and the figures presented are best effort estimates only. The data used is based on actual 2011 figures, or extrapolated from earlier years to 2011 equivalent values if not available.

Part 1. Research Funding

From Chapter 4, we could see that funding for research and human capital development in Malaysia is relatively poor compared to its economic strength. To make a recommendation that addresses this problem, first we need to establish what a desirable level of investment should be, and over what period this should be achieved.

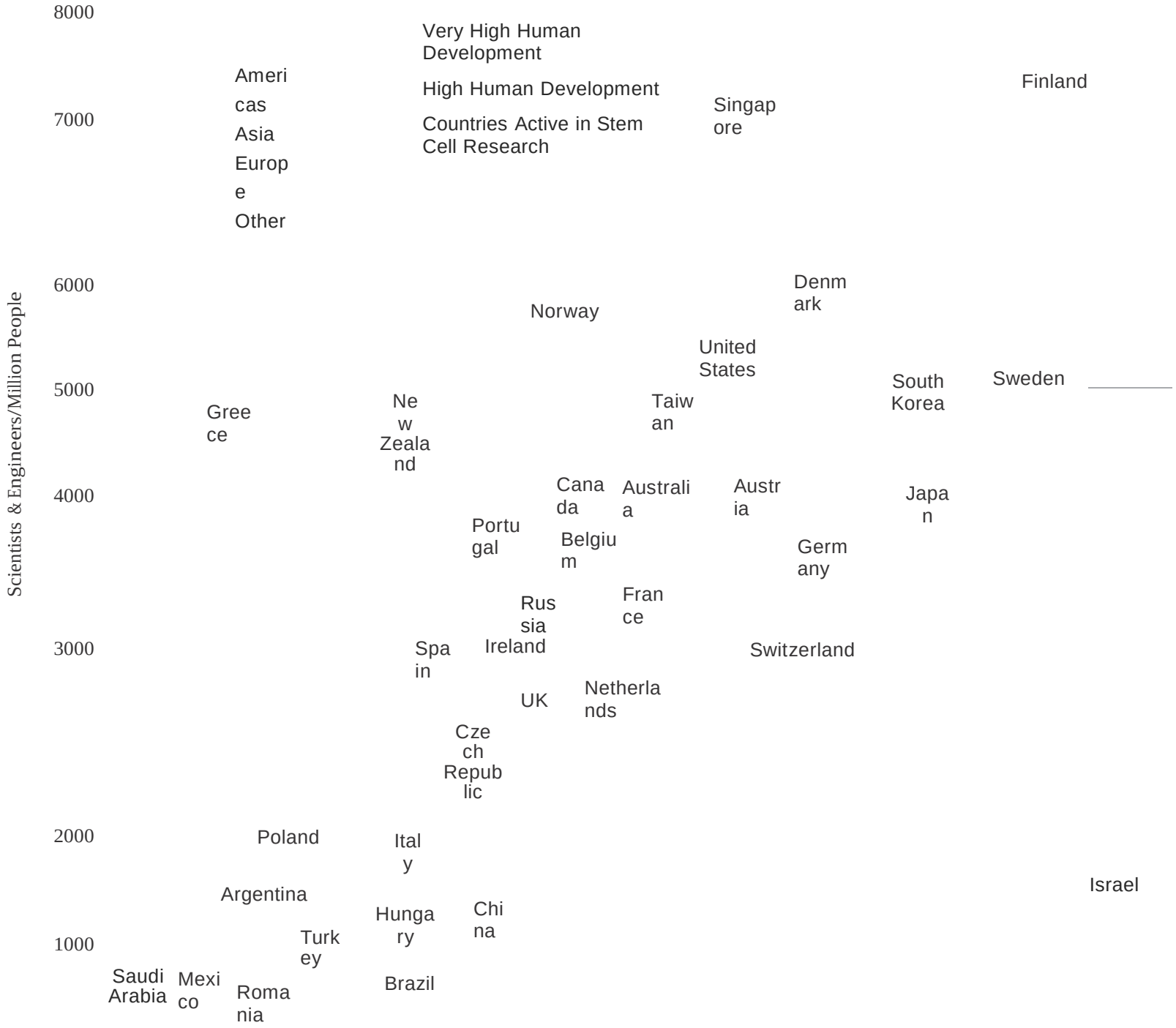
As Malaysia intends to become a fully developed nation by 2020, this is an appropriate benchmark to use as the basis of this analysis (3). To assess the development status of a country, the United Nations Development Programme (UNDP) uses the Human Development Index (HDI), which is a measure that allows comparison of life expectancy, literacy, education, and standards of living between regions (4). Utilising the HDI instead of per capita national income is a superior way of assessing development status, as this is reflected in the daily lives of the population in that region. A developed nation according to the UNDP is defined as a country in the top quartile of HDI, while a developing nation is in one of the bottom three quartiles (*Figure 1*).

Based on UNDP data for 2011, Malaysia has a high HDI (second quartile), and ranked 61 out of 187 nations. When Malaysia is measured against other countries of similar development level, its research funding is seen to be fairly good and manpower levels appropriate in comparison (*Figure 2*). However, if Malaysia is intending to achieve developed nation status by 2020, these indicators still need further improvement, especially for manpower development.

If we are aiming to reach the lowest quartile targets for developed nations by 2020, research funding is already on target, but manpower needs to be increased substantially on a sustained basis (10.9% per annum). However, this will not be sufficient to remain competitive in highly contested fields such as biotechnology and especially stem cell research. Hence, aiming for the median or even highest quartile targets may be a better proposition, but will require significantly more investment by the government (*Table 2*).

The next part of the analysis looks at the proportion of research expenditure specifically targeted at stem cell therapy. The appropriate benchmark for this would be the United States, which has been gradually building up its research capacity in this vital area. Based on data from 2002–2010, funding for all types of stem cell research by the National Institutes of Health (NIH) has been rapidly increasing at a compound annual growth rate of 13% (*Table 3*). The NIH accounts for most of the US government funding for medical research, and this implies that the figures for NIH stem cell research funding can be taken to approximate the US government commitment to this field.

The percentage of US government funding for stem cell research out of the total national research expenditure can also be similarly calculated, and it can be seen that this figure has been steadily rising to about 0.36% (*Table 4*). Based on Malaysia's 2010 GDP of US$238 billion, a growth rate of 5% in 2011 and a forecasted growth rate of 4% in 2012, Malaysia's 2012 GDP should be about US$260 billion (6, 8). Using the median target for research expenditure (*Table 2*), Malaysia's 2012 national research spending as a percentage of GDP should be 1.15%, or US$3.0 billion. If we apply the current US percentage for stem cell therapy funding, this works out to US$10.75 million or RM32 million for 2012. To put this figure in context, the cumulative funding awarded over the past 10 years for stem cell research amounts to approximately RM35 million, of which 50% was allocated as high impact research block grants (HIRG-MOHE) to Universiti Malaya (*Appendix Table 4-I*).


Scientists & Engineers/Million People
8000
7000
6000
5000
4000
3000
2000
1000
Very High Human Development
High Human Development
Countries Active in Stem Cell Research
Americas
Asia
Europe
Other
Finland
Singapore
Denmark
Norway
United States
South Korea
Sweden
Greece
New Zealand
Taiwan
Canada
Australia
Austria
Japan
Portugal
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Argentina
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China
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Saudi Arabia
Mexico
Romania
Brazil

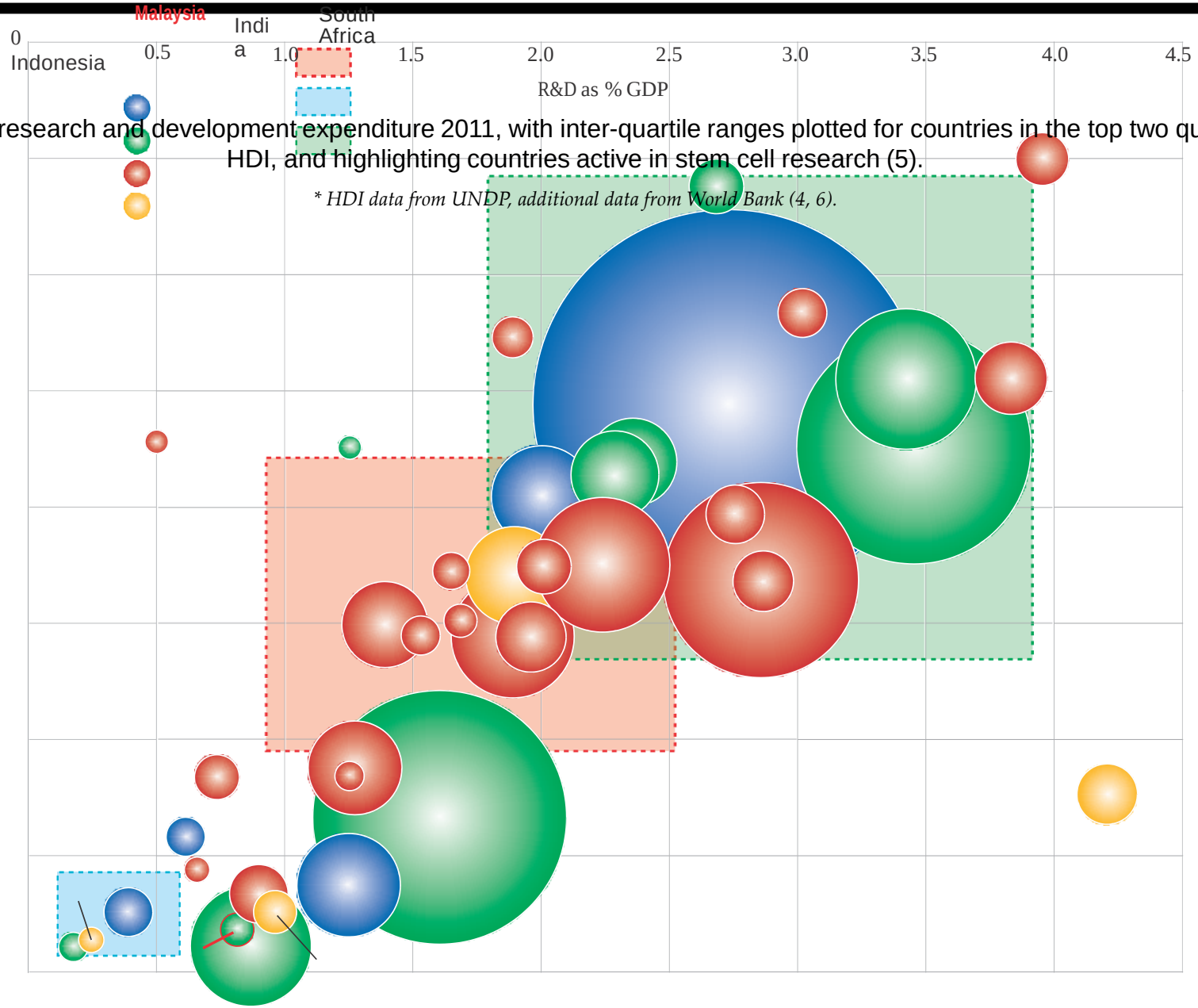

Fig. 2 World research and development expenditure 2011, with inter-quartile ranges plotted for countries in the top two quartiles of HDI, and highlighting countries active in stem cell research (5).

** HDI data from UNDP, additional data from World Bank (4, 6).*

TABLE 2. PROJECTED INCREASE IN RESEARCH EXPENDITURE AND MANPOWER REQUIRED TO ACHIEVE DEVELOPED NATION STATUS BY 2020, ACCORDING TO QUARTILE TARGETS

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	CAGR
	Lowest quartile										
R&D**	1.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Researchers	756	839	930	1032	1144	1269	1407	1561	1731	1919	10.9%
	Median										
R&D	1.09	1.15	1.21	1.27	1.34	1.41	1.49	1.57	1.65	1.74	5.3%
Researchers	756	894	1057	1250	1479	1748	2067	2445	2891	3418	18.2%
	Highest quartile										
R&D	1.09	1.20	1.31	1.44	1.59	1.74	1.91	2.10	2.31	2.54	9.9%
Researchers	756	920	1120	1363	1659	2019	2458	2991	3640	4430	21.7%

** R&D - research expenditure as percentage of GDP, Researchers - per million population, CAGR - compound annual growth rate*
*** already reached lowest quartile target*
† R&D and researchers for 2011 estimated based on 2006 figures and a historical CAGR of 11.4% and 15.3% respectively

TABLE 3. NIH STEM CELL RESEARCH FUNDING, FY 2002–2010 (7)

	Human		Non-human		
Year	**Embryonic**	**Non-embryonic**	**Embryonic**	**Non-embryonic**	**Total**
2002	10.1	170.9	71.5	134.1	386.6
2003	20.3	190.7	113.5	192.1	516.6
2004	24.3	203.2	89.3	235.7	552.5
2005	39.6	199.4	97.1	273.2	609.3
2006	37.8	206.1	110.4	288.7	643.0
2007	42.1	203.5	105.9	305.9	657.4
2008	88.1	297.2	149.7	497.4	1032.4
2009	142.6	397.2	177.2	638.3	1355.3
2010	165.2	414.4	194.9	643.8	1418.3

** all figures are in millions of USD, 2011 adjusted values*

TABLE 4. US GOVERNMENT STEM CELL RESEARCH FUNDING AS A PERCENTAGE OF TOTAL NATIONAL RESEARCH EXPENDITURE, FY 2002–2010 (6, 7)

	US GDP	R&D%GDP	R&D Expenditure	SC NIH	SC%R&D
2002	10,590,200.0	2.70%	285,935.4	386.6	0.14%
2003	11,089,200.0	2.70%	299,408.4	516.6	0.17%
2004	11,812,300.0	2.60%	307,119.8	552.5	0.18%
2005	12,579,700.0	2.60%	327,072.2	609.3	0.19%
2006	13,336,200.0	2.70%	360,077.4	643.0	0.18%
2007	13,995,000.0	2.70%	377,865.0	657.4	0.17%
2008	14,296,900.0	2.80%	400,313.2	1,032.4	0.26%
2009	14,048,100.0	2.69%	377,291.8	1,355.3	0.36%
2010	14,586,700.0	2.69%	391,757.1	1,418.3	0.36%

** all figures are in millions of USD, 2011 adjusted values*

*** R&D%GDP - US total national research expenditure as a percentage of GDP, SC NIH - stem cell research funding by the US National Institutes of Health (NIH), SC%R&D - NIH stem cell research funding as a percentage of US total national research expenditure*

Part 2: Research Manpower

From *Table 2*, it can be seen that the targets for research manpower are higher than those for research funding, requiring a 10–20% annual increase over the next decade. For comparison, the historical growth rate for research manpower from 1996–2006 averaged 15.3% per annum (6). To make a recommendation on this issue, we first need to consider the factors that influence research manpower.

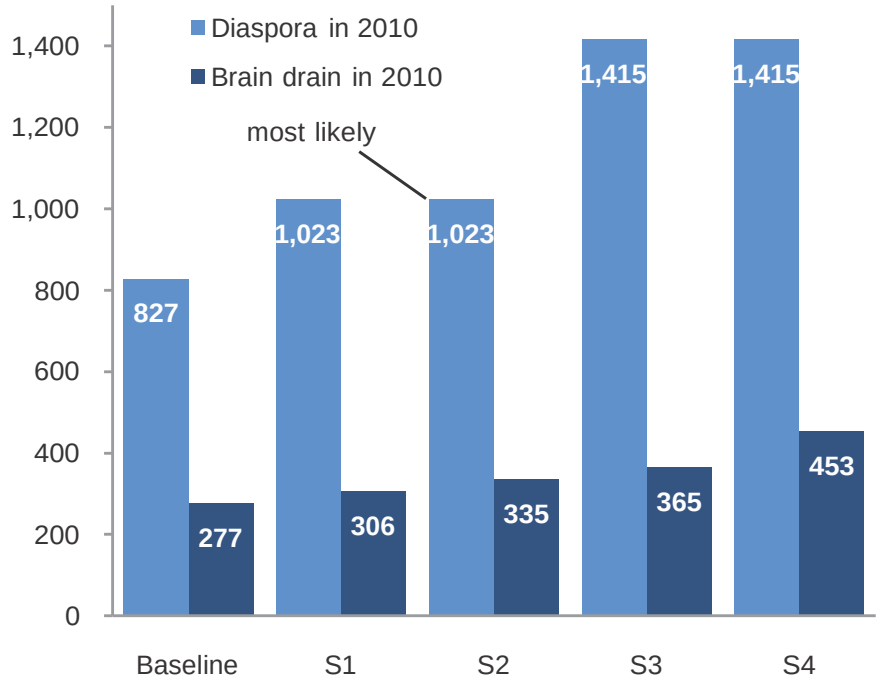

Figure 3. World Bank simulations of the Malaysian diaspora (9).

** Diaspora (age 0+) and brain drain (age 25+) estimates, 2010, worldwide, thousands.*

According to the World Bank, more than 1 million Malaysians live abroad, of which 57% have moved to neighbouring Singapore, with 180,000 being tertiary-educated (*Figure 3, 4*) (9). Emigration of Malaysians to the rest of the world broadly follows the same pattern, with about 335,000 highly qualified people living abroad, which is approximately 10% of all Malaysians who have tertiary- level education (10). This brain drain is not replaced by inward migration, in that more than 60% of migrants into Malaysia possess primary-level education or less (*Figure 5*) (9).

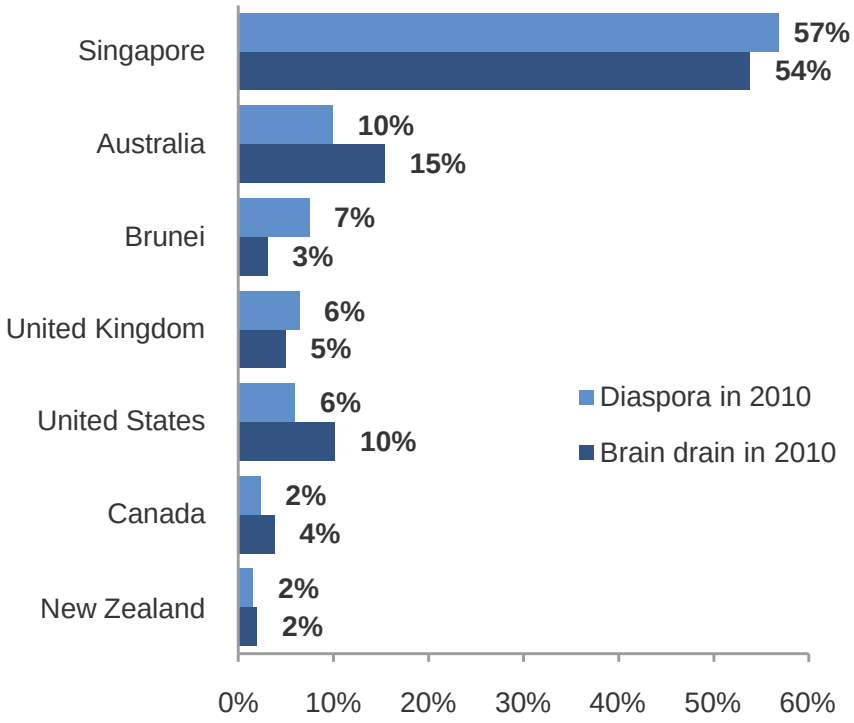

Figure 4. World Bank simulations of the Malaysian diaspora, scenario 2 (S2) (9).

** Diaspora (age 0+) and brain drain (age 25+) estimates, 2010.*

Based on World Bank figures for Singapore (total population 5.08 million; 4.19 million over 15 years old; labour participation rate 65%; 24% of labour force having tertiary qualifications), we can estimate that approximately 650,000 of the active Singapore labour force possesses tertiary-level qualifications (11). If we assume that the workforce of Malaysian origin broadly follows the same pattern (180,000 tertiary education; labour participation rate 65%), approximately 117,000 of the active Singapore labour force with tertiary-level qualifications originate from Malaysia, or about 18% of the total.

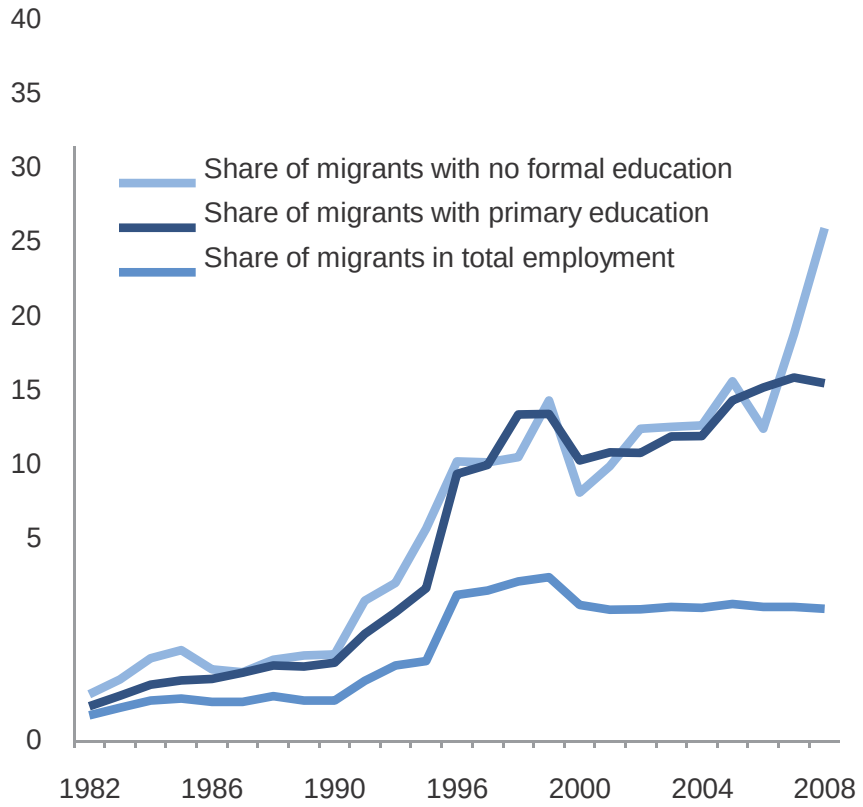

Figure 5. *Share of immigrants into Malaysia with primary-level education or less (9).*

As Singapore has 31,000 researchers (total population 5.08 million; 6088 researchers per million population), and if 18% of these are of Malaysian origin, this works out to 5,600 researchers (6, 11). If this pattern holds for the Malaysian diaspora as a whole, then approximately 10,400 researchers of Malaysian origin work abroad. Malaysia has 21,500 researchers (total population 28.40 million; 756 researchers per million population) working locally, implying that 33% of our total research manpower is working abroad (6, 10).

This means that if we only intend to achieve the lowest quartile targets for research manpower, our current growth rates should suffice. However, if we want to match the countries which are active in stem cell research (*Figure 2*), then we will need to attract overseas Malaysian researchers to return and work locally. If we are aiming for the highest quartile, then we would need to adjust our migration policy to accept a higher proportion of skilled immigrants to make up the difference. Based on a 22% increase in research manpower per annum (*Table 2*, highest quartile), and a historical performance of 15%, the growth difference that needs to be made up is about 7% per annum. This will comprise of both returning Malaysians and new migrants, which amounts to 1500 researchers for 2012. If we are only aiming for the median, then we will need to bring in 650 researchers for 2012. This analysis refers to researchers across all fields, as it is not possible to specifically identify 'stem cell researchers' as many conduct their work across multiple disciplines.

TCM, Regenerative Medicine, and Ageing

Currently, there is very little published research investigating the role of TCM in both regenerative medicine and stem cell therapy. While a number of herbs have been extensively used for their anti-ageing properties, not much is known about their mechanisms of action. Of particular interest are the small molecule active compounds in these herbs, and whether they are able to regulate the proliferation or differentiation of stem cells within the body.

Scientists in Malaysia have several advantages in this field of research. First, there are multiple established TCM traditions locally due to the diverse ethnic mix, which broadens the potential avenues for investigation. Regenerative medicine and stem cell research is fairly active in Malaysia, with a number of hospitals providing stem cell therapy services, thus facilitating clinical trials. Internationally, there is relatively little competition in this area of study, especially from well funded research programmes in developed nations. Finally, the indigenous peoples in Malaysia have a wealth of traditional knowledge about the medicinal properties of various forest herbs, and this knowledge should be tapped to best utilise the nation's biodiversity.

Overall Recommendations

TABLE 5. PROBLEMS FACING STEM CELL RESEARCH IN MALAYSIA AND RECOMMENDED SOLUTIONS

Problem	Solution
Limited resources	Choose high-yield areas to direct research
Slow grant approval process	Set up a special review panel for stem cell grants
Grant reviewers not experts in stem cell research	Appoint experts in the field to the review panel
Poor communication between local research groups	Set up a coordinating body
Difficult to get data about local stem cell research	Have a clearinghouse for local publications
Relatively little clinical stem cell research	Fund translational research

While at first glance (see chapter 4), there may seem to be a big gulf between Malaysia and the developed nations in the resources allocated to stem cell research, on careful analysis our country appears to be well-positioned to close the gap. This is due in part to the rapid pace of expansion of our local research infrastructure. Based on the present trajectory, Malaysia should meet the lowest quartile targets for developed countries by 2020 in both research funding and manpower.

This is however insufficient where the highly contested field of stem cell research is concerned given that it is projected to dominate life sciences research within five years, and Malaysia is competing against countries with advanced research capabilities. If we were to wait until 2020, our local stem cell research is likely to be marginalised by our competitors.

From chapter 2, we see that even though Malaysia is a developing nation, the pattern of our research in the field of stem cell therapy

is like that of a developed country. This implies that the local research infrastructure is fairly advanced, giving us an advantage in that we are well positioned to translate pre-clinical research into clinical trials within the same country. In addition, TCM in stem cell therapy is an area where we have built-in advantages, and where there is little competition elsewhere.

In order to successfully implement stem cell translational research, there needs to be adequate funding, manpower, and infrastructure allocated for this purpose. Our research manpower status is relatively good given our current state of development, as we had the advantage of being pioneers in this field. The infrastructure is also adequate, with one commercial laboratory having Good Manufacturing Practice (GMP) certification (*Appendix Table 2-IA*), and a number of others in the process of obtaining it. However, as other countries are investing heavily in stem cell research, we need to match their investment especially with regards to research funding in order to maintain our competitive edge.

Given that resources are always limited, we need to think out of the box and see if there are ways in which we can achieve more within these limitations. Based on the points raised in *Table 5*, there is a good case to set up a single coordinating body that encompasses all the functions described. As the National Science and Research Council (NSRC) has been tasked with overseeing allocation of research and development funding, and providing strategic input on science and technology to the government of Malaysia, it would be appropriate for the Stem Cell Institute to be set up under the Council's sponsorship (12).

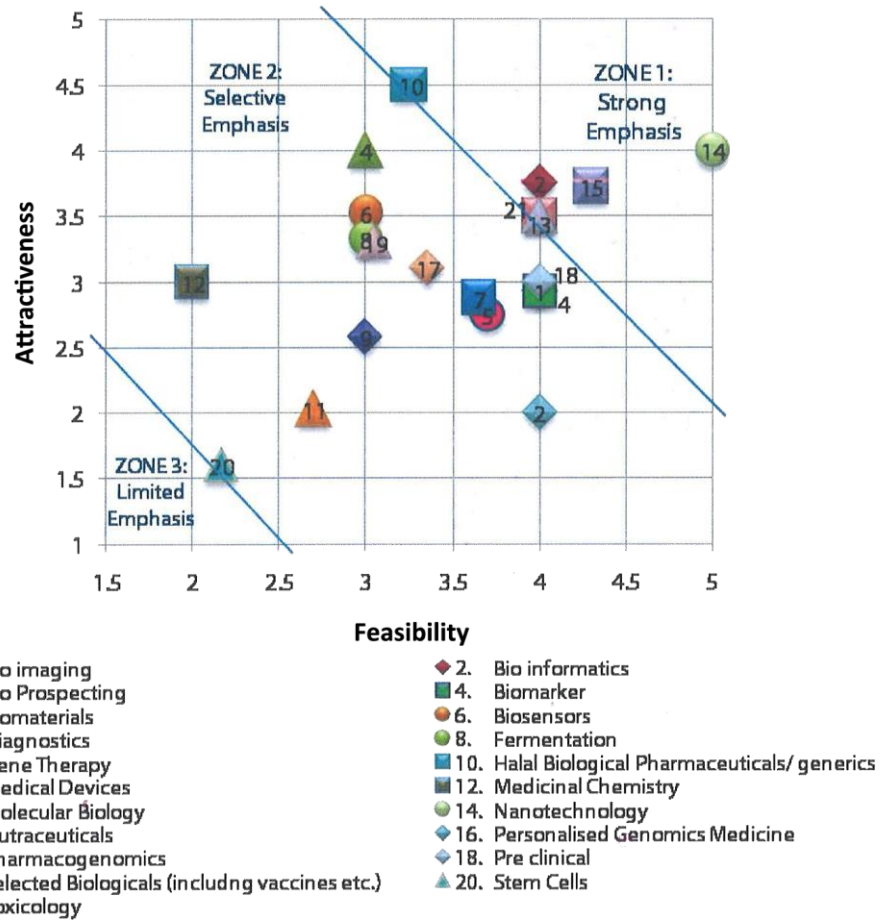

Figure 6. Prioritisation of healthcare biotechnology areas from the National Technology Foresight 2010 report.

This Institute would not conduct any in-house research, but rather function to oversee the development of stem cell research nationally. Funding bodies could channel a block grant to the Institute which would then disburse it to researchers, prioritising high-yield areas like translational research and TCM, and ensuring that the various groups coordinate their efforts. Foreign stem cell experts could also be invited to periodically review the research

priorities of the Institute, to ensure that its direction remains up to date, especially in such a fast changing field.

Finally, the recent National Technology Foresight 2010 report based on Malaysian expert opinion placed stem cell research lowest in priority in terms of attractiveness and feasibility among the twenty areas examined in healthcare biotechnology, while nanotechnology was ranked highest (*Figure 6*). A sentiment analysis on stem cells also demonstrated that the lay public in Malaysia generally have a negative view on stem cell technology, compared with the rest of the world (*Figure 7*).

However, when stem cell technology and nanotechnology are compared objectively, we see that the level of interest among the lay public is far higher for stem cells both in Malaysia and globally (*Figure 8, 9*). Moreover the historical trend over the past decade indicates that in the area of healthcare, interest in stem cell technology is consistently far higher than for nanotechnology (*Figure 10*). It has been demonstrated both in Chapter 4 and earlier in this chapter that with the proper investment in funds and manpower, Malaysia has the capacity to be competitive in this strategic technology. However for this to happen, we need to counteract the negative perception of the field from both scientific experts and the lay public. This is where the Stem Cell Institute would have a major role to play in public education, improving communication between researchers, and generally raising the visibility of this field in Malaysia.

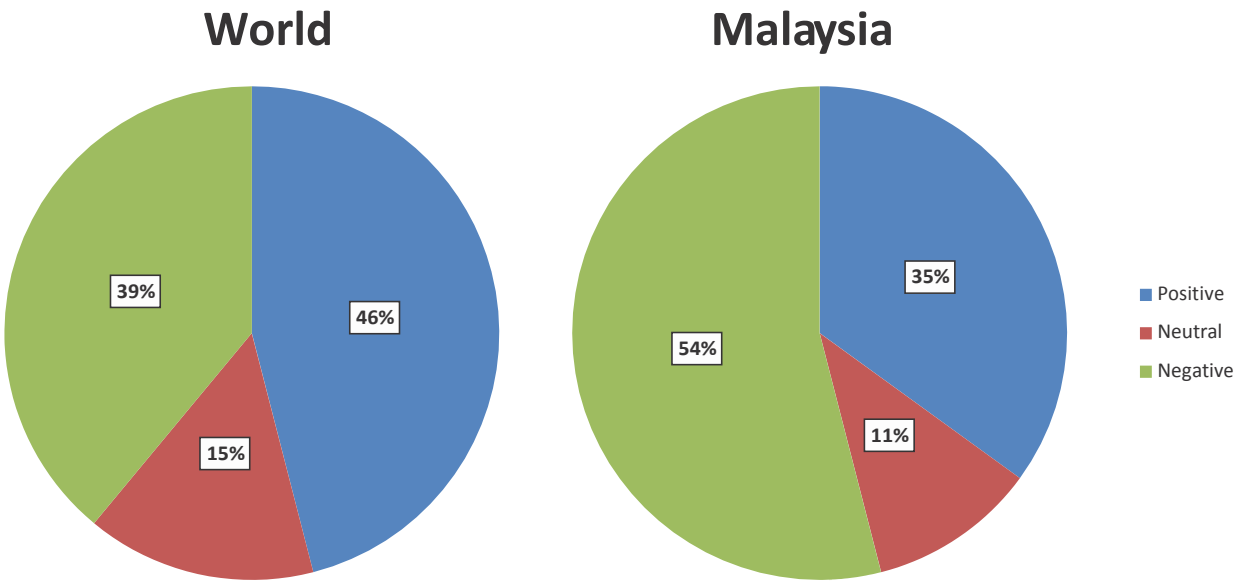

Figure 7. Sentiment analysis on stem cells.

** based on Opinion Crawl™ search June 2012.*

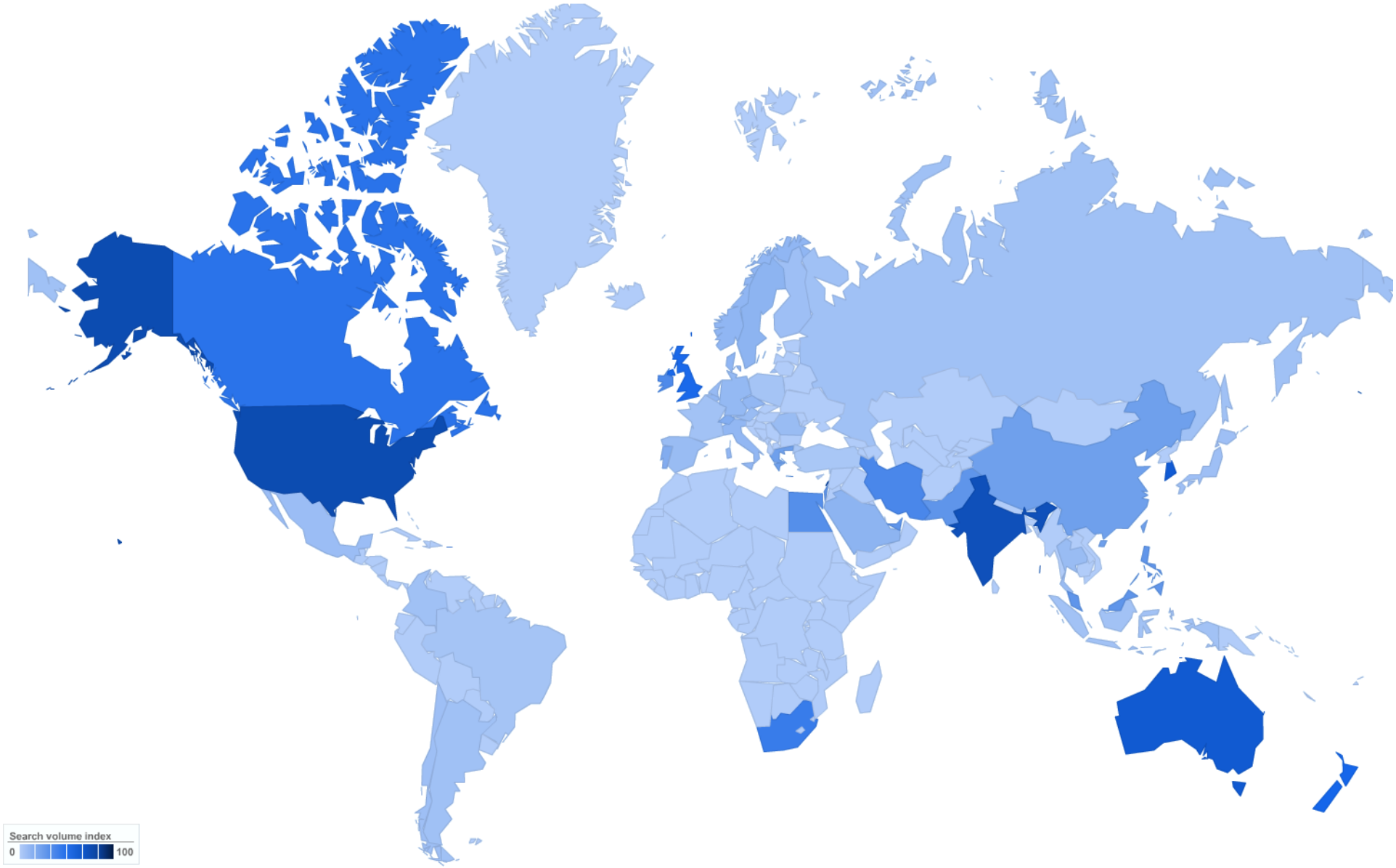

Figure 8. Geographical intensity of interest for stem cells.

** based on Google Insights™ search June 2012.*

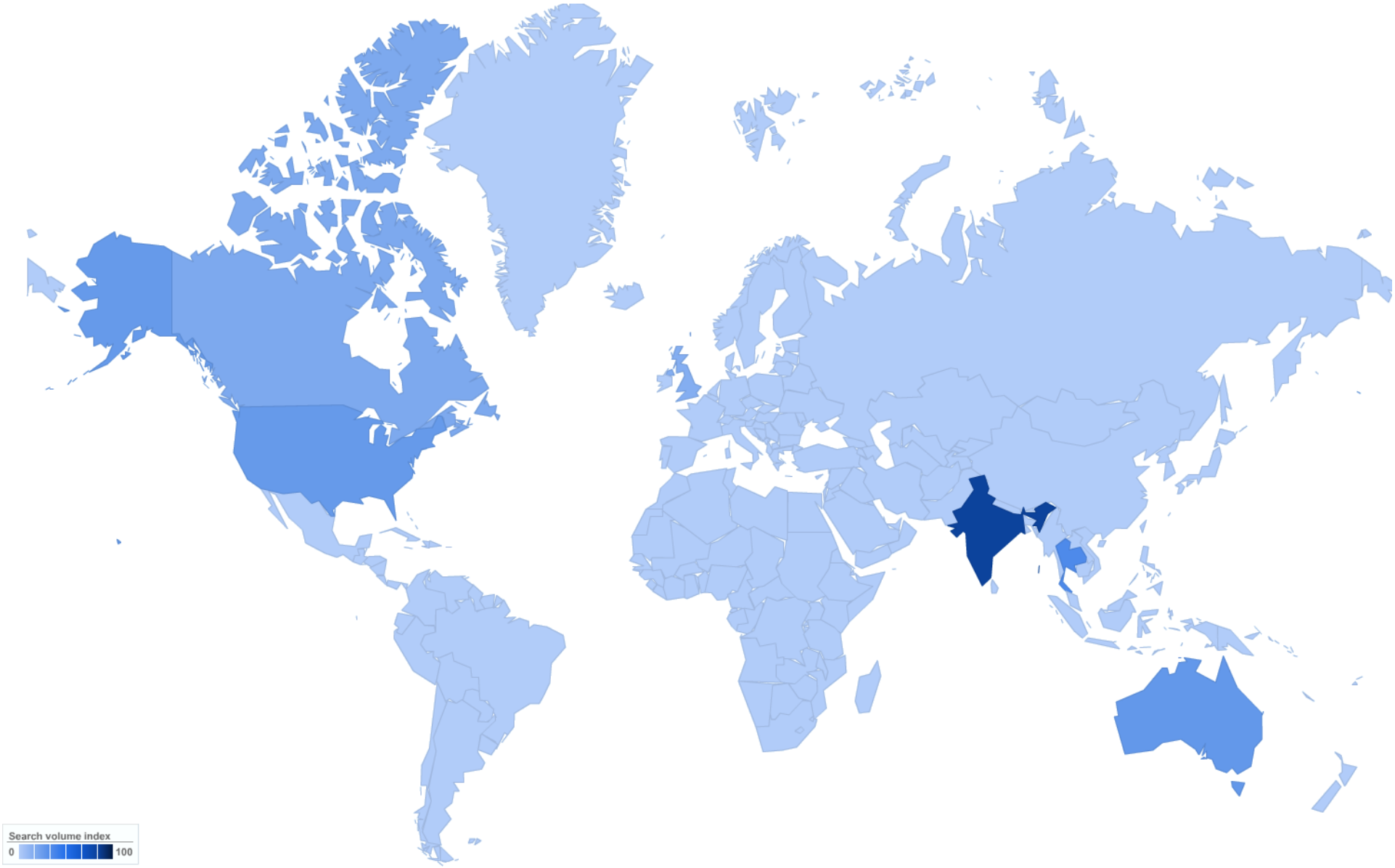

Figure 9. Geographical intensity of interest for nanotechnology.

** based on Google Insights™ search June 2012.*

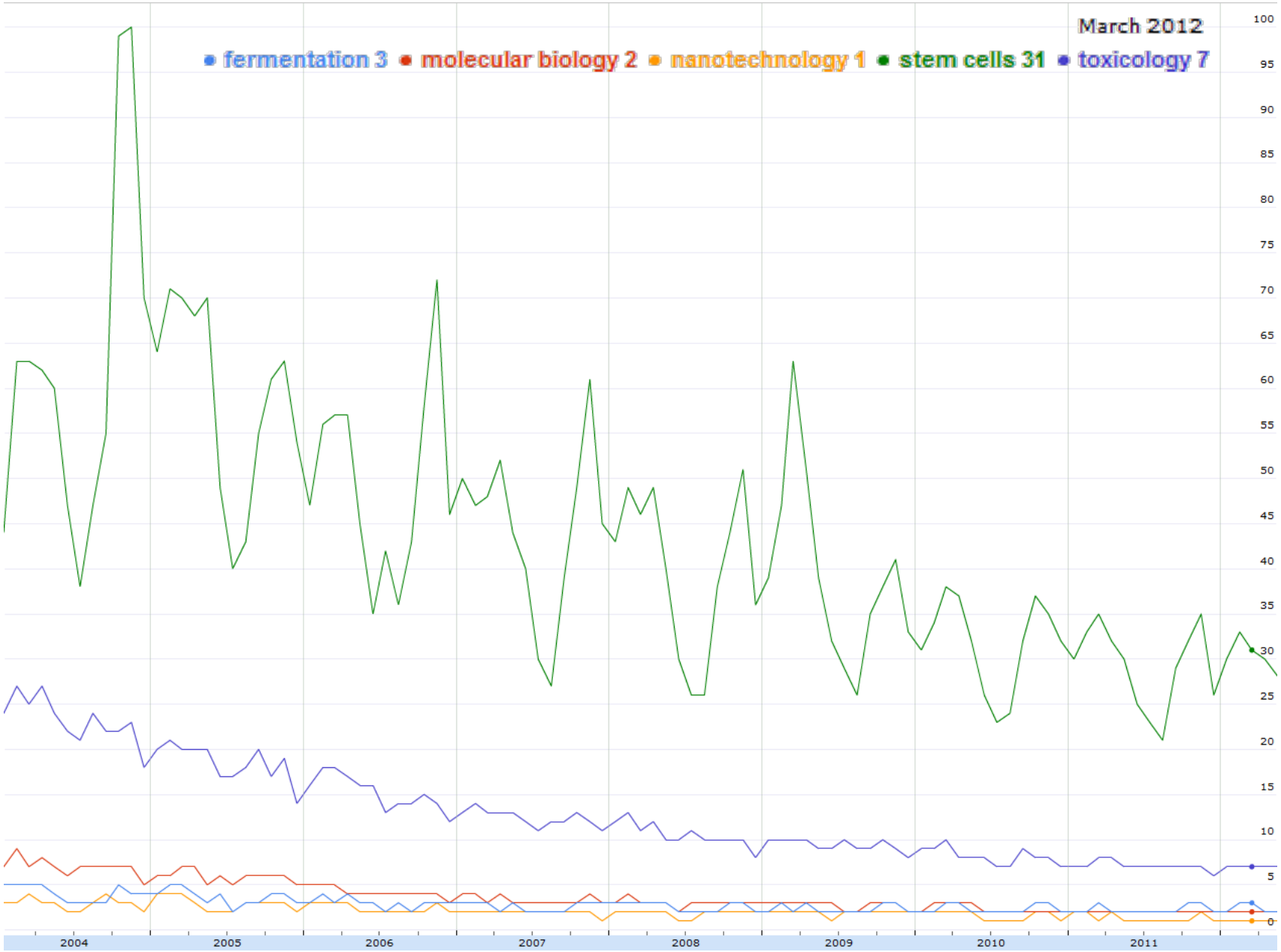

Figure 10. Historical intensity of interest for stem cells, nanotechnology, and other selected areas in healthcare biotechnology

** based on Google Insights™ search June 2012.*

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CHAPTER 7. GLOSSARY

Chronic non-communicable disease
A chronic non-communicable disease is a medical condition or disease which by definition is non-infectious and non-transmissible between persons, and is of long duration and slow progression.

Compounded annual growth rate
The compounded annual growth rate (CAGR) is a term for the smoothed annualised gain of an investment over a given time period.

Cord blood bank
A cord blood bank is a facility which stores umbilical cord blood for future use.

Demographic transition
A demographic transition refers to the transition from high birth and death rates to low birth and death rates as a country develops from a pre-industrial to an industrialized economic system.

Demographic window
Demographic window is defined to be that period of time in a nation's demographic evolution when the proportion of population of working age group is particularly prominent.

Dependency Ratio
The dependency ratio is an age-population ratio of those typically not in the labor force (the dependent part) and those typically in the labor force (the productive part). It is used to measure the pressure on productive population.

Disability
Disability is an umbrella term, covering impairments, activity limitations, and participation restrictions. An impairment is a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. Thus disability is a complex phenomenon, reflecting an interaction between features of a person's body and features of the society in which he or she lives.

Disability Threshold
The level of disability for a population beyond which an individual is unable to function independently in society, requires care from others, and becomes what is conventionally known as "disabled".

Disability-Adjusted Life Years
The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

* most glossary terms are extracts from the English edition of Wikipedia (http://en.wikipedia.org)

Embryonic stem cells
Embryonic stem cells are pluripotent stem cells derived from the inner cell mass of the blastocyst, an early-stage embryo.

Gap analysis
A gap analysis is a technique that helps compare actual performance with potential performance.

Good manufacturing practice
Good manufacturing practice (GMP) is a set of production and testing procedures that help to ensure a quality product, thus safeguarding the health of the patient. Complying with GMP is a mandatory aspect in pharmaceutical manufacturing.

Human development index
The human development index (HDI) is a composite statistic used to rank countries by standard of living. Utilising the HDI instead of per capita national income is a superior way of assessing development status.

Pluripotent
Pluripotent stem cells have the potential to differentiate into any of the three germ layers: endoderm (interior stomach lining, gastrointestinal tract, the lungs), mesoderm (muscle, bone, blood, urogenital), or ectoderm (epidermal tissues and nervous system). Pluripotent stem cells can give rise to any foetal or adult cell type.

Regenerative Medicine
Regenerative medicine is the process of replacing or regenerating human cells, tissues or organs to restore or establish normal function.

Reproductive Cloning
Reproductive cloning is the creation of a genetically identical copy of an existing or previously existing human.

Stem Cells
Stem cells are biological cells found in all multi-cellular organisms that can divide and differentiate into diverse specialized cell types and can self-renew to produce more stem cells. There are two broad types of stem cells: embryonic stem cells, which are isolated from the inner cell mass of blastocysts, and adult stem cells, which are found in various tissues.

Therapeutic Cloning (Somatic-Cell Nuclear Transfer)
Therapeutic cloning is a laboratory technique for creating a clone embryo with a donor nucleus.

Translational Research
Translational research is a way of thinking about and conducting scientific research to make the results of research applicable to the population under study.

Xenotransplantion
Xenotransplantation is the transplantation of living cells, tissues or organs from one species to another. Such cells, tissues or organs are called xenografts or xenotransplants.

* most glossary terms are extracts from the English edition of Wikipedia (http://en.wikipedia.org)

CHAPTER 8. APPENDIX

TABLE 2-IA. COMPANIES OFFERING STEM CELL THERAPY SERVICES

Provider name	Notes
Niscell	Nichi-Asia Centre for Stem Cells and Regenerative Medicine (NiSCELL) is a Malaysian Biotechnology Company which has Bionexus status and a GMP certified laboratory. NiSCELL provides autologous stem cell therapy for various diseases.
Stempeutics Research	Stempeutics Research is an emerging stem cell company mainly focused on research, therapy and therapeutics in the field of regenerative medicine. The company has BioNexus status and is part of Manipal Education & Medical Group. The company goal is to develop cell based therapeutics using human adult mesenchymal stem cells derived from bone marrow.
Cytopeutics	Cytopeutics is one of the pioneers in stem cell research and treatment. The company has research in heart failure, myocardial infarction, refractory angina, peripheral arterial disease, osteoarthritis, and diabetic foot ulcer, using autologous stem cells. The company goal is to bring comprehensive stem cell treatment solutions to Malaysia and the Asia Pacific.

PROVIDER NAME	NOTES
CryoCord	CryoCord prides itself to be the premier stem cell bank in South-East Asia with a Class 100 clean room laboratory. The company is the first in South-East Asia to foray into the isolation and processing of mesenchymal stem cells, and its facilities are both ISO9001 and ISO15189 certified.
CellSafe International	CellSafe International Group is a regional biotechnology group that focuses on non-embryonic sources of stem cells. The company specializes mainly in the harvesting and cryogenic preservation of cord blood stem cells.
StemLife	StemLife is the first stem cell banking and therapeutics company in Malaysia. The company has MSC and BioNexus status. The company offers banking facilities for umbilical cord and peripheral blood stem cells.
EmCell	EmCell clinic offers anti-ageing treatment with foetal stem cells.
StemTech International	Provides cord blood and adult stem cell banking (collection / harvesting, processing and storage), stem cell medical therapy, as well as R&D for the purpose of future stem cell technology improvements and medical therapy.

** The advisory report does not endorse any of the providers listed above, and the list is not exhaustive.*

TABLE 2-IB. STEM CELL THERAPY PROVIDERS IN PRIVATE MEDICAL CENTRES

Provider name	Notes
Gleneagles Medical Centre Penang	Provides stem cell therapy for blood cancers / blood disorders, using autologous stem cells. They offer therapies in leukaemia, lymphoma, myeloma, sickle cell anaemia and thalassaemia.
Kuala Lumpur Sports Medicine Centre	Provides articular cartilage regeneration with peripheral mobilised stem cells.
Tropicana Medical Centre	Offers stem cell banking and therapy services through StemTech International (see Table 2-1A).
Sime Darby Healthcare	Offers bone marrow transplantation for adults and children.
International Specialist Eye Centre	Dr Then Kong Yong, an ophthalmologist who had done keratoprosthesis and stem cell treatment for corneal stem cell deficiency.
Penang Adventist Hospital	Cytopeutics and Stempeutics provide stem cells for intractable heart failure cases.

** The advisory report does not endorse any of the providers listed above, and the list is not exhaustive.*

TABLE 2-II ACTIVE RESEARCHERS IN STEM CELL RESEARCH, BY INSTITUTION

Researchers
Faculty of Medicine, Universiti Kebangsaan Malaysia (UKM)
Prof Dr Ruszymah Bt Hj Idrus
Prof Dato' Dr Lokman Saim
Prof Dr S Fadilah Abd Wahid
Prof Dr A Rahman A Jamal
Prof Dr Noor Hamidah Hussin
Assoc Prof Dr Leong Chooi Fun
Assoc Prof Dr Goh Bee See
Assoc Prof Dr Tan Geok Chin
Assoc Prof Dr Amaramalar Selvi Naicker
Assoc Prof Dr Asma Abdullah
Assoc Prof Dr Zulkifli Zainuddin
Dr Abdul Halim Abd Rashid
Dr Angela Ng Min Hwei
Dr Shalimar Abdullah
Dr Rashidah Ismail @ Ohnmar Htwe
Dr Nor Hazla Mohamed Haflah
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TABLE 2-III. JOURNAL ARTICLES BY MALAYSIAN AUTHORS ON STEM CELL RESEARCH

Institution	Authors	Title	Reference	Year	IF
IIU	Munirah S, Samsudin OC, Aminuddin BS, Ruszymah BH.	Expansion of human articular chondrocytes and formation of tissue-engineered cartilage: a step towards exploring a potential use of matrix-induced cell therapy.	Tissue Cell. 2010 Oct;42(5): 282-92.	2010	1.698

Institution	Authors	Title	Reference	Year	IF
IMR	Lim MN, Umapathy T, Baharuddin PJ, Zubaidah Z.	Characterization and safety assessment of bioengineered limbal epithelium.	Med J Malaysia. 2011 Oct; 66(4):335-41.	2011	0.000

Institution	Authors	Title	Reference	Year	IF
IMU	Wong RS.	Extrinsic factors involved in the differentiation of stem cells into insulin-producing cells: an overview.	Exp Diabetes Res. 2011;2011:406182.	2011	1.528
IMU	Wong RS.	Mesenchymal stem cells: angels or demons?	J Biomed Biotechnol. 2011;2011:459510.	2011	1.230
IMU	Chin SP, Poey AC, Wong CY, Chang SK, Teh W, Mohr TJ, Cheong SK.	Cryopreserved mesenchymal stromal cell treatment is safe and feasible for severe dilated ischemic cardiomyopathy.	Cytotherapy. 2010;12(1):31-7.	2010	2.925
IMU	Yap FL, Cheong SK, Ammu R, Leong CF.	Transfected human mesenchymal stem cells do not lose their surface markers and differentiation properties.	Malays J Pathol. 2009 Dec; 31(2):113-20.	2009	0.000
IMU	Tan EL, Selvaratnam G, Kananathan R, Sam CK.	Quantification of Epstein-Barr virus DNA load, interleukin-6, interleukin-10, transforming growth factor-beta1 and stem cell factor in plasma of patients with nasopharyngeal carcinoma.	BMC Cancer. 2006 Sep 24;6:227.	2006	3.153

Institution	Authors	Title	Reference	Year	IF
UiTM	Salin N, Ishak AK, Abdul Rahman S, Ali M, Nawawi HM, Said MS, Froemming GA.	In-vitro expression of adhesion molecules and bone specific markers are depending on the cell culture material.	Med J Malaysia. 2008 Jul;63 Suppl A:67-8.	2008	0.000

Institution	Authors	Title	Reference	Year	IF
UKM	Mok PL, Cheong SK, Leong CF, Chua KH, Ainoon O.	Extended and stable gene expression via nucleofection of MIDGE construct into adult human marrow mesenchymal stromal cells.	Cytotechnology. 2012 Mar; 64(2):203-16.	2012	1.277
UKM	Fariha MM, Chua KH, Tan GC, Tan AE, Hayati AR.	Human chorion-derived stem cells: changes in stem cell properties during serial passage.	Cytotherapy. 2011 May;13(5): 582-93.	2011	2.925
UKM	Hayati AR, Nur Fariha MM, Tan GC, Tan AE, Chua K.	Potential of human decidua stem cells for angiogenesis and neurogenesis.	Arch Med Res. 2011 May; 42(4):291-300.	2011	1.986
UKM	Wan Safwani WK, Makpol S, Sathapan S, Chua KH.	The changes of stemness biomarkers expression in human adipose-derived stem cells during long-term manipulation.	Biotechnol Appl Biochem. 2011 Jul-Aug;58(4):261-70. doi: 10.1002/bab.38.	2011	1.512
UKM	Ishak MF, Chua KH, Asma A, Saim L, Aminuddin BS, Ruszymah BH, Goh BS.	Stem cell genes are poorly expressed in chondrocytes from microtic cartilage.	Int J Pediatr Otorhinolaryngol. 2011 Jun; 75(6):835-40.	2011	1.067
UKM	Ruszymah BH, Chua KH, Mazlyzam AL, Aminuddin BS.	Formation of tissue engineered composite construct of cartilage and skin using high density polyethylene as inner scaffold in the shape of human helix.	Int J Pediatr Otorhinolaryngol. 2011 Jun; 75(6):805-10.	2011	1.067

UKM	Harun MH, Sepian SN, Chua KH, Ropilah AR, Abd Ghafar N, Che-Hamzah J, Bt Hj Idrus R, Annuar FH.	Human forniceal region is the stem cell-rich zone of the conjunctival epithelium.	Hum Cell. 2011 Jul 12.	2011	0.750
UKM	Alfaqeh HH, Hui CK, Saim AB, Idrus RB.	Growth medium with low serum and transforming growth factor beta 3 promotes better chondrogenesis of bone marrow-derived stem cells in vitro and in vivo.	Saudi Med J. 2011 Jun;32(6): 640-1.	2011	0.560
UKM	Yazid MD, Zainal Ariffin SH, Senafi S, Zainal Ariffin Z, Megat Abdul Wahab R.	Stem cell heterogeneity of mononucleated cells from murine peripheral blood: molecular analysis.	ScientificWorldJournal. 2011;11:2150-9.	2011	0.000
UKM	Mohd Heikal MY, Aminuddin BS, Jeevanan J, Chen HC, Sharifah SH, Ruszymah BH.	Autologous implantation of bilayered tissue-engineered respiratory epithelium for tracheal mucosal regenesis in a sheep model.	Cells Tissues Organs. 2010;192(5):292-302.	2010	2.302
UKM	Fatimah SS, Ng SL, Chua KH, Hayati AR, Tan AE, Tan GC.	Value of human amniotic epithelial cells in tissue engineering for cornea.	Hum Cell. 2010 Nov;23(4): 141-51. doi: 10.1111/j. 1749-0774.2010.00096.x.	2010	0.750
UKM	Tan YF, Leong CF, Cheong SK.	Observation of dendritic cell morphology under light, phase-contrast or confocal laser scanning microscopy.	Malays J Pathol. 2010 Dec; 32(2):97-102.	2010	0.000
UKM	Fadilah SA, Goh KY.	Breast and ovarian recurrence of acute lymphoblastic leukaemia after allogeneic peripheral blood haematopoietic stem cell transplantation.	Singapore Med J. 2009 Dec; 50(12):e407-9.	2009	0.730

UKM	Ng MH, Aminuddin BS, Hamizah S, Lynette C, Mazlyzam AL, Ruszymah BH.	Correlation of donor age and telomerase activity with in vitro cell growth and replicative potential for dermal fibroblasts and keratinocytes.	J Tissue Viability. 2009 Nov; 18(4):109-16.	2009	0.000
UKM	Rafeah NT, Fadilah SA.	The A-B-C of haematopoietic stem cell transplantation.	Med J Malaysia. 2009 Mar; 64(1):94-100.	2009	0.000
UKM	Mok PL, Cheong SK, Leong CF, Othman A.	In vitro expression of erythropoietin by transfected human mesenchymal stromal cells.	Cytotherapy. 2008;10(2): 116-24.	2008	2.925
UKM	Wong CY, Cheong SK, Mok PL, Leong CF.	Differentiation of human mesenchymal stem cells into mesangial cells in post-glomerular injury murine model.	Pathology. 2008 Jan;40(1):52-7.	2008	2.168
UKM	Abdul Rahman H, Manzor NF, Tan GC, Tan AE, Chua KH.	Upregulation of SOX-2, FZD9, Nestin, OCT-4 and FGF-4 expression in human chorion derived-stem cells after angiogenic induction.	Med J Malaysia. 2008 Jul;63 Suppl A:57-8.	2008	0.000
UKM	Adha PR, Chua KH, Mazlyzam AL, Low KC, Aminuddin BS, Ruszymah BH.	Usage of allogeneic single layered tissue engineered skin enhance wound treatment in sheep.	Med J Malaysia. 2008 Jul;63 Suppl A:30-1.	2008	0.000
UKM	Alfaqeh H, Chua KH, Aminuddin BS, Ruszymah BH.	Effects of different media on the in vivo chondrogenesis of sheep bone marrow stem cells: histological assessment.	Med J Malaysia. 2008 Jul;63 Suppl A:119-20.	2008	0.000
UKM	Alfaqeh H, Norhamdan MY, Chua KH, Chen HC, Aminuddin BS, Ruszymah BH.	Cell based therapy for osteoarthritis in a sheep model: gross and histological assessment.	Med J Malaysia. 2008 Jul;63 Suppl A:37-8.	2008	0.000
UKM	Aminuddin BS, Ruszymah BH.	Tissue engineering research in developing countries, the significant and differences as compared to the developed countries.	Med J Malaysia. 2008 Jul;63 Suppl A:47-8.	2008	0.000

UKM	Fazlina N, Maha A, Zarina AL, Hamidah A, Zulkifli SZ, Cheong SK, Ainoon O, Jamal R, Hamidah NH.	Assessment of P-gp and MRP1 activities using MultiDrugQuant Assay Kit: a preliminary study of correlation between protein expressions and its functional activities in newly diagnosed acute leukaemia patients.	Malays J Pathol. 2008 Dec; 30(2):87-93.	2008	0.000
UKM	Hamid AA, Ruszymah BH, Aminuddin BS, Sathappan S, Chua KH.	Differential gene expression of human adipose-derived stem cells in osteogenic induction.	Med J Malaysia. 2008 Jul;63 Suppl A:9-10.	2008	0.000
UKM	Heikal MY, Aminuddin BS, Jeevanan J, Chen HC, Sharifah S, Ruszymah BH.	A scanning electron microscopic study of in vivo tissue engineered respiratory epithelium in sheep.	Med J Malaysia. 2008 Jul;63 Suppl A:34.	2008	0.000
UKM	Hidayah HN, Mazzre M, Ng AM, Ruszymah BH, Shalimar A.	Approaches to deriving Schwann cells from human bone marrow for neural tube regeneration in a clinical setting.	Med J Malaysia. 2008 Jul;63 Suppl A:39-40.	2008	0.000
UKM	Leong CF, Habsah A, Teh HS, Goh KY, Fadilah SA, Cheong SK.	Isolation of purified autologous peripheral blood CD34+ cells with low T cell content using CliniMACS device--a local experience.	Malays J Pathol. 2008 Jun; 30(1):31-6.	2008	0.000
UKM	Manzor NF, Chua KH, Tan GC, Tan AE, Abdul Rahman H.	Augmentation of angiogenic and endothelial associated gene expression by EDM50 in human chorion-derived stem cells.	Med J Malaysia. 2008 Jul;63 Suppl A:11-2.	2008	0.000
UKM	Mok PL, Cheong SK, Leong CF.	In-vitro differentiation study on isolated human mesenchymal stem cells.	Malays J Pathol. 2008 Jun; 30(1):11-9.	2008	0.000

UKM	Munirah S, Samsudin OC, Chen HC, Salmah SH, Aminuddin BS, Ruszymah BH.	Measurement of sulphated glycosaminoglycans production after autologous 'chondrocytes-fibrin' constructs implantation in sheep knee joint.	Med J Malaysia. 2008 Jul;63 Suppl A:35-6.	2008	0.000
UKM	Ng AM, Kojima K, Kodoma S, Ruszymah BH, Aminuddin BS, Vacanti AC.	Isolation techniques of murine bone marrow progenitor cells and their adipogenic, neurogenic and osteogenic differentiation capacity.	Med J Malaysia. 2008 Jul;63 Suppl A:121-2.	2008	0.000
UKM	Ng AM, Westerman K, Kojima K, Kodoma S, Aminuddin BS, Ruszymah BH, Vacanti CA.	Derivation of neurospheres from bone marrow stromal cells.	Med J Malaysia. 2008 Jul;63 Suppl A:7-8.	2008	0.000
UKM	Nizam MH, Ruszymah BH, Chua KH, Ghafar NA, Hamzah JC.	Ex vivo growth of rabbit bulbar, fornix and palpebral conjunctival epithelia in a serum-free and feeder layer-free culture system.	Med J Malaysia. 2008 Jul;63 Suppl A:111-2.	2008	0.000
UKM	Ruszymah BH.	Tissue engineering provides the potential to replace and regenerate.	Med J Malaysia. 2008 Jul;63 Suppl A:27-8.	2008	0.000
UKM	Simat SF, Chua KH, Abdul Rahman H, Tan AE, Tan GC.	The stemness gene expression of cultured human amniotic epithelial cells in serial passages.	Med J Malaysia. 2008 Jul;63 Suppl A:53-4.	2008	0.000
UKM	Tan GC, Simat SF, Abdul Rahman H, Tan AE, Chua KH.	Quantitative RT PCR approach to evaluate the neurogenic and gliagenic gene expression of cultured human amniotic epithelial cells.	Med J Malaysia. 2008 Jul;63 Suppl A:51-2.	2008	0.000
UKM	Yazid AG, Anuar A, Onhmar HT, Ng AM, Ruszymah BH, Amaramalar SN.	Sourcing different neuro-progenitor cell for the use of nerve construct.	Med J Malaysia. 2008 Jul;63 Suppl A:113-4.	2008	0.000

UKM	Zaman WS, Makpol S, Santhapan S, Chua KH.	Stemness gene expression profile of human adipose derived stem cells in long-term culture.	Med J Malaysia. 2008 Jul;63 Suppl A:61-2.	2008	0.000
UKM	Fadilah SA, Vuckovic S, Khalil D, Hart DN.	Cord blood CD34+ cells cultured with FLT3L, stem cell factor, interleukin-6, and IL-3 produce CD11c+CD1a-/c- myeloid dendritic cells.	Stem Cells Dev. 2007 Oct; 16(5):849-55.	2007	4.791
UKM	Choong PF, Mok PL, Cheong SK, Leong CF, Then KY.	Generating neuron-like cells from BM-derived mesenchymal stromal cells in vitro.	Cytotherapy. 2007;9(2):170-83.	2007	2.925
UKM	Choong PF, Mok PL, Cheong SK, Then KY.	Mesenchymal stromal cell-like characteristics of corneal keratocytes.	Cytotherapy. 2007;9(3):252-8.	2007	2.925
UKM	Azma RZ, Hamidah NH, Leong CF, Ainoon O, Cheong SK.	Assessing donor chimerism using flow cytometry in paroxysmal nocturnal haemoglobinuria after stem cell transplantation--a case report.	Malays J Pathol. 2006 Dec; 28(2):107-12.	2006	0.000
UKM	Leong CF, Cheong SK, Fadilah SA, Ainoon O, Hamidah NH.	Allogeneic haemopoietic stem cell transplantation using non-myeloablative conditioning--a local experience.	Med J Malaysia. 2003 Jun; 58(2):229-35.	2003	0.000
UKM	Mok PL, Leong CF, Cheong SK.	Isolation and identification of putative mesenchymal stem cells from bone marrow.	Malays J Pathol. 2003 Dec; 25(2):121-7.	2003	0.000
UKM	S-Abdul-Wahid F, Soon-Keng C.	Stomatocytic elliptocytosis and 'neutrophil drumsticks' as a marker of stem cell engraftment.	Br J Haematol. 2002 Mar; 116(4):731.	2002	4.942
UKM	Wahid FS, Cheong SK, Sivagengei K.	Autoimmune thrombocytopenia and neutropenia after autologous peripheral blood stem cell transplantation.	Acta Haematol. 2002;107(4): 237-8.	2002	1.316
UKM	Cheong SK, Eow GI, Leong CF.	Non-myeloablative conditioning for hemopoietic stem cell transplantation--does it work?	Malays J Pathol. 2002 Jun; 24(1):1-8.	2002	0.000

Institution	Authors	Title	Reference	Year	IF
UM	Krishnamurithy G, Shilpa PN, Ahmad RE, Sulaiman S, Ng CL, Kamarul T.	Human amniotic membrane as a chondrocyte carrier vehicle/substrate: in vitro study.	J Biomed Mater Res A. 2011 Dec 1;99(3):500-6. doi: 10.1002/jbm.a.33184.	2011	3.044
UM	Dashtdar H, Rothan HA, Tay T, Ahmad RE, Ali R, Tay LX, Chong PP, Kamarul T.	A preliminary study comparing the use of allogenic chondrogenic pre-differentiated and undifferentiated mesenchymal stem cells for the repair of full thickness articular cartilage defects in rabbits.	J Orthop Res. 2011 Sep;29(9): 1336-42. doi: 10.1002/jor. 21413.	2011	2.976
UM	Govindasamy V, Ronald VS, Abdullah AN, Ganesan Nathan KR, Aziz ZA, Abdullah M, Zain RB, Kasim NH, Musa S, Bhonde RR.	Human platelet lysate permits scale-up of dental pulp stromal cells for clinical applications.	Cytotherapy. 2011 Nov;13(10): 1221-33.	2011	2.925
UM	Boo L, Selvaratnam L, Tai CC, Ahmad TS, Kamarul T.	Expansion and preservation of multipotentiality of rabbit bone-marrow derived mesenchymal stem cells in dextran-based microcarrier spin culture.	J Mater Sci Mater Med. 2011 May;22(5):1343-56.	2011	2.325
UM	Kanthan SR, Kavitha G, Addi S, Choon DS, Kamarul T.	Platelet-rich plasma (PRP) enhances bone healing in non-united critical-sized defects: a preliminary study involving rabbit models.	Injury. 2011 Aug;42(8):782-9.	2011	2.269
UM	Yusoff N, Abu Osman NA, Pingguan-Murphy B.	Design and validation of a bi-axial loading bioreactor for mechanical stimulation of engineered cartilage.	Med Eng Phys. 2011 Jul;33(6): 782-8.	2011	1.909
UM	Kadri NA, Raha MG, Pingguan-Murphy B.	Polyvinyl alcohol as a viable membrane in artificial tissue design and development.	Clinics (Sao Paulo). 2011;66(8):1489-94.	2011	1.422

UM	Moo EK, Osman NA, Pingguan-Murphy B.	The metabolic dynamics of cartilage explants over a long-term culture period.	Clinics (Sao Paulo). 2011;66(8):1431-6.	2011	1.422
UM	Choong SS, Rosmanizam S, Ibrahim K, Gan GG, Ariffin H.	Development of an algorithm of satellite markers for monitoring chimerism status in post-allogeneic haematopoietic stem cell transplantation patients.	Int J Lab Hematol. 2011 Apr; 33(2):182-6. doi: 10.1111/j. 1751-553X.2010.01264.x.	2011	1.368
UM	Tan SL, Sulaiman S, Pingguan-Murphy B, Selvaratnam L, Tai CC, Kamarul T.	Human amnion as a novel cell delivery vehicle for chondrogenic mesenchymal stem cells.	Cell Tissue Bank. 2011 Feb; 12(1):59-70.	2011	1.157
UM	Daud SS, Ibrahim K, Choong SS, Vengidasan L, Chong LA, Ariffin H.	Microfluidic chip-based assay for post-hematopoietic stem cell transplantation chimerism monitoring using polymorphic tandem repeat markers.	Anal Biochem. 2010 Feb 15;397(2):181-5.	2010	3.236
UM	Gan G, Teh A, Chan L, Cheong S, Chang K, Ibrahim H.	Bone marrow and stem cell transplantation: Malaysian experience.	Bone Marrow Transplant. 2008 Aug;42 Suppl 1:S103-S105.	2008	3.660
UM	Bee PC, Gan GG, Sangkar VJ, Haris AR.	Nephrotic syndrome in a patient with relapsed of chronic myeloid leukemia after peripheral blood stem cell transplantation.	Med J Malaysia. 2008 Mar; 63(1):71-2.	2008	0.000
UM	Gan GG, Zakaria Z, Sangkar JV, Haris AR, Bee PC, Chin E, Teh A.	Adult allogeneic haematopoietic stem cell transplantation: a single centre experience in Malaysia.	Med J Malaysia. 2008 Oct; 63(4):281-7.	2008	0.000
UM	Ariffin H, Daud SS, Mohamed Z, Ibrahim K, Lee TF, Chong LA.	Evaluation of two short tandem repeat multiplex systems for post-haematopoietic stem cell transplantation chimerism analysis.	Singapore Med J. 2007 Apr; 48(4):333-7.	2007	0.730

Institution	Authors	Title	Reference	Year	IF
UPM	Ramasamy R, Tong CK, Yip WK, Vellasamy S, Tan BC, Seow HF.	Basic fibroblast growth factor modulates cell cycle of human umbilical cord-derived mesenchymal stem cells.	Cell Prolif. 2012 Apr;45(2): 132-9. doi: 10.1111/j. 1365-2184.2012.00808.x.	2012	2.742
UPM	Fonseka M, Ramasamy R, Yip WK, Tan BC, Seow HF.	Human Umbilical Cord Blood-Derived Mesenchymal Stem Cells (hUCB-MSC) Inhibits the Proliferation of K562 (Human Erythromyeloblastoid Leukemic Cell Line).	Cell Biol Int. 2012 Feb 16.	2012	1.747
UPM	Maqbool M, Vidyadaran S, George E, Ramasamy R.	Human mesenchymal stem cells protect neutrophils from serum-deprived cell death.	Cell Biol Int. 2011 Dec 1;35(12):1247-51.	2011	1.747
UPM	Tong CK, Vellasamy S, Tan BC, Abdullah M, Vidyadaran S, Seow HF, Ramasamy R.	Generation of mesenchymal stem cell from human umbilical cord tissue using a combination enzymatic and mechanical disassociation method.	Cell Biol Int. 2011 Mar 1;35(3): 221-6.	2011	1.747
UPM	Lai MI, Wendy-Yeo WY, Ramasamy R, Nordin N, Rosli R, Veerakumarasivam A, Abdullah S.	Advancements in reprogramming strategies for the generation of induced pluripotent stem cells.	J Assist Reprod Genet. 2011 Apr;28(4):291-301.	2011	1.253
UPM	Loke SC, Chin SP, Sivanandam S, Goh PP, Ng RK, Saw KY, Lim TO.	The National Stem Cell Therapy Patient Registry of Malaysia--measuring clinical outcomes of stem cell therapy.	Stem Cell Rev. 2010 Dec;6(4): 507-11.	2010	6.774

UPM	Ooi YY, Ramasamy R, Rahmat Z, Subramaiam H, Tan SW, Abdullah M, Israf DA, Vidyadaran S.	Bone marrow-derived mesenchymal stem cells modulate BV2 microglia responses to lipopolysaccharide.	Int Immunopharmacol. 2010 Dec;10(12):1532-40.	2010	2.325
UPM	Sarmadi VH, Tong CK, Vidyadaran S, Abdullah M, Seow HF, Ramasamy R.	Mesenchymal stem cells inhibit proliferation of lymphoid origin haematopoietic tumour cells by inducing cell cycle arrest.	Med J Malaysia. 2010 Sep; 65(3):209-14.	2010	0.000
UPM	Ramasamy R, Tong CK, Seow HF, Vidyadaran S, Dazzi F.	The immunosuppressive effects of human bone marrow-derived mesenchymal stem cells target T cell proliferation but not its effector function.	Cell Immunol. 2008 Feb; 251(2):131-6.	2008	2.575
UPM	Ferdaos N, Nathan S, Nordin N.	Prospective full-term-derived pluripotent amniotic fluid stem (AFS) cells.	Med J Malaysia. 2008 Jul;63 Suppl A:75-6.	2008	0.000
UPM	Masrudin SS, Ghafar NA, Saidi M, Aminuddin BS, Rahmat A, Ruszymah BH, Othman F.	Scanning electron microscopy of cornea re-epithelization after transplanted with bilayered corneal construct.	Med J Malaysia. 2008 Jul;63 Suppl A:109-10.	2008	0.000
UPM	Ooi YY, Ramasamy R, Vidyadaran S.	Mouse bone marrow mesenchymal stem cells acquire CD45-CD106+ immunophenotype only at later passages.	Med J Malaysia. 2008 Jul;63 Suppl A:65-6.	2008	0.000
UPM	Sarmadi VH, Heng FS, Ramasamy R.	The effect of human mesenchymal stem cells on tumour cell proliferation.	Med J Malaysia. 2008 Jul;63 Suppl A:63-4.	2008	0.000
UPM	Tong CK, Seow HF, Ramasamy R.	Cord blood-derived mesenchymal stem cell does not stimulate nor inhibits T lymphocytes activation.	Med J Malaysia. 2008 Jul;63 Suppl A:77-8.	2008	0.000

Institution	Authors	Title	Reference	Year	IF
USM	Dorai AA, Lim CK, Fareha AC, Halim AS.	Cultured epidermal autografts in combination with MEEK Micrografting technique in the treatment of major burn injuries.	Med J Malaysia. 2008 Jul;63 Suppl A:44.	2008	0.000
USM	Rashid SA, Halim AS, Muhammad NA.	The effect of vitamin E on basic fibroblast growth factor level in human fibroblast cell culture.	Med J Malaysia. 2008 Jul;63 Suppl A:69-70.	2008	0.000
USM	Al-Salihi KA.	Tissue-engineered bone via seeding bone marrow stem cell derived osteoblasts into coral: a rat model.	Med J Malaysia. 2004 May;59 Suppl B:200-1.	2004	0.000

Institution	Authors	Title	Reference	Year	IF
KLSMC	Saw KY, Anz A, Merican S, Tay YG, Ragavanaidu K, Jee CS, McGuire DA.	Articular cartilage regeneration with autologous peripheral blood progenitor cells and hyaluronic acid after arthroscopic subchondral drilling: a report of 5 cases with histology.	Arthroscopy. 2011 Apr;27(4): 493-506.	2011	3.317
KLSMC	Saw KY, Hussin P, Loke SC, Azam M, Chen HC, Tay YG, Low S, Wallin KL, Ragavanaidu K.	Articular cartilage regeneration with autologous marrow aspirate and hyaluronic Acid: an experimental study in a goat model.	Arthroscopy. 2009 Dec;25(12): 1391-400	2009	3.317
Stempeutics	Govindasamy V, Ronald VS, Abdullah AN, Nathan KR, Ab Aziz ZA, Abdullah M, Musa S, Kasim NH, Bhonde RR.	Differentiation of dental pulp stem cells into islet-like aggregates.	J Dent Res. 2011 May;90(5): 646-52.	2011	3.773

Stempeutics	Govindasamy V, Abdullah AN, Ronald VS, Musa S, Ab Aziz ZA, Zain RB, Totey S, Bhonde RR, Abu Kasim NH.	Inherent differential propensity of dental pulp stem cells derived from human deciduous and permanent teeth.	J Endod. 2010 Sep;36(9): 1504-15.	2011	3.291
Stempeutics (IMR/MOH)	Mamidi MK, Pal R, Mori NA, Arumugam G, Thrichelvam ST, Noor PJ, Abdullah HM, Gupta PK, Das AK, Zakaria Z, Bhonde R.	Co-culture of mesenchymal-like stromal cells derived from human foreskin permits long term propagation and differentiation of human embryonic stem cells.	J Cell Biochem. 2011 May; 112(5):1353-63. doi: 10.1002/ jcb.23052.	2011	3.122
Stempeutics (IMR/MOH)	Mamidi MK, Pal R, Govindasamy V, Zakaria Z, Bhonde R.	Treat the graft to improve the regenerative ability of the host.	Med Hypotheses. 2011 Apr; 76(4):599-601.	2011	1.389
Stempeutics	Das AK, Gopurappilly R, Parhar I.	Current status and prospective application of stem cell-based therapies for spinal cord injury.	Curr Stem Cell Res Ther. 2011 Jun;6(2):93-104.	2011	0.000
Stempeutics	Das AK, Pal R.	Induced pluripotent stem cells (iPSCs): the emergence of a new champion in stem cell technology-driven biomedical applications.	J Tissue Eng Regen Med. 2010 Aug;4(6):413-21.	2010	3.534
Stempeutics	Govindasamy V, Abdullah AN, Ronald VS, Musa S, Ab Aziz ZA, Zain RB, Totey S, Bhonde RR, Abu Kasim NH.	Inherent differential propensity of dental pulp stem cells derived from human deciduous and permanent teeth.	J Endod. 2010 Sep;36(9): 1504-15.	2010	3.291

Stempeutics (IMR/MOH)	Mamidi MK, Pal R, Bhonde R, Zakaria Z, Totey S.	Application of multiplex PCR for characterization of human embryonic stem cells (hESCs) and its differentiated progenies.	J Biomol Screen. 2010 Jul; 15(6):630-43.	2010	2.500
Stempeutics (IMR/MOH)	Govindasamy V, Ronald VS, Totey S, Din SB, Mustafa WM, Totey S, Zakaria Z, Bhonde RR.	Micromanipulation of culture niche permits long-term expansion of dental pulp stem cells--an economic and commercial angle.	In Vitro Cell Dev Biol Anim. 2010 Oct;46(9):764-73.	2010	0.000
Stempeutics	Totey S, Totey S, Pal R, Pal R.	Adult stem cells: a clinical update.	J Stem Cells. 2009;4(2):105-21.	2009	0.000
Mawar Hospital	Chin SP, Poey AC, Wong CY, Chang SK, Tan CS, Ng MT, Chew KH, Lam KH, Cheong SK.	Intramyocardial and intracoronary autologous bone marrow-derived mesenchymal stromal cell treatment in chronic severe dilated cardiomyopathy.	Cytotherapy. 2011 Aug;13(7): 814-21.	2011	2.925

Institution	Authors	Title	Reference	Year	IF
Not Stated	Fadilah SA, Leong CF, Cheong SK.	Stem cell transplantation in Malaysia and future directions.	Med J Malaysia. 2008 Oct; 63(4):279-80.	2008	0.000

** Indexed by Pubmed Medline as of March 2012. All impact factors (IF) from Thomson ISI Web of Knowledge 2011 database. The institution listed is the primary corresponding address for the article.*
*** Note: the list may not be comprehensive, and includes only articles where the corresponding institution is in Malaysia.*

TABLE 4-I.0 LIST OF GRANT RECIPIENTS FOR STEM CELL RESEARCH BY UNIVERSITY

Grant	Project	Primary investigator	Quantum*
UKM			
IRPA	Identification of genes involved in osteoblast and osteoclast differentiation from progenitor cells	Shahrul Hisham Zainal Ariffin	RM208k
IRPA	Production of mesenchymal stem cells for transplantation and as vehicles for gene therapy	Cheong Soon Keng	RM665k
FRGS	Understanding molecular signature of leukaemia stem cells by targeting genes regulating hematopoietic stem cells fate	Zariyantey Abdul Hamid	
FRGS	Determination of human mononucleated peripheral blood cells in cellular differentiation capacity	Shahrul Hisham Zainal Ariffin	
FRGS	Cell-based therapy for osteoarthritis in a sheep model	Ruszymah Idrus	RM145k
Sciencefund	The regeneration of tooth from human dental pulp stem cells	Mohd Nazimi Abd Jabar	RM150k
Sciencefund	The formation of tissue engineered conjunctiva for the treatment of pterygium	Jemaima binti Che Hamzah	RM228k
Sciencefund	Reconstruction of external ear via tissue engineering technology utilizing co-polyester materials in sheep model for future clinical application	Goh Bee See	RM241k
Sciencefund	Reconstruction of tissue-engineered human neural tube for future clinical application in nerve injury	Shalimar Abdullah	RM223k
Sciencefund	Peripheral nerve regeneration via tissue engineering technique for the treatment of paralysis	Amaramalar Selvi Naicker	RM243k
Sciencefund	Regeneration of alveolar bone via tissue engineering technique to facilitate dental implant atrophic alveolar bone - an animal study	Roszalina Ramli	RM281k
Sciencefund	Potential clinical use of stem cells from human placental and umbilical cord matrix for tissue repair through angiogenesis	Hayati Abd Rahman	RM250k

Sciencefund	The isolation of amnion stem cells and characterization of its potential in skin regeneration	Tan Geok Chin	RM250k
Sciencefund	Explore the potential of human lipoaspirate stem cells for future clinical treatment of cartilage loss	Chua Kien Hui	RM250k
Sciencefund	Stem cells: chemotaxis activity in human progenitor osteoblast cells	Shahrul Hisham bin Zainal Ariffin	RM200k
RUGS	A phase II clinical study assessing the efficacy of intramuscular autologous bone marrow mononuclear cells plus mesenchymal stem cell implantation versus autologous bone marrow mononuclear cells implantation only in patients with chronic critical limb ischemia.		RM30k
RUGS	The effect of autologous human serum on culture and expansion of autologous dermal fibroblast.		RM30k
ERGS	Controlled, open label, phase II study assessing the efficacy of intracoronary autologous mesenchymal stem cells in patients with ischemic dilated cardiomyopathy.		RM294k
UKM Internal	A Phase II study assessing the efficacy of intra-articular autologous mesenchymal stem cells in patients with mild to moderate osteoarthritis.		RM232k
UKM Internal	Isolation of a clonal mesenchymal stem cell line from the human bone marrow and their capacity to differentiate into functional hepatocyte.		RM98k
UKM Internal	Mechanism of benzene-induced hematotoxicity and leukomogenicity: implication on self-renewing, differentiation and apoptosis controlling genes of hematopoietic stem cells.		RM50k
UPM Funding	Potential of channa striatus (Haruan) fillet extracts for anticancer property in stem cells.		RM30k

InnoBio	Production of functional human hepatocytes from bone marrow derived mesenchymal stem cells, adipose-tissue stem cells and embryonic stem cells.		RM3828k

Grant	Project	Primary investigator	Quantum*
UM			
HIRG-MOHE	Understanding the fundamental aspects through molecular and cellular studies to determine the lineage commitment mechanisms involved in mesenchymal stem cells differentiation for potential upscaling and clinical applications	Tunku Kamarul Zaman	RM12489k
HIRG-MOHE	Dental derived stem cells for regenerative therapies.	Noor Hayaty Abu Kasim	RM3170k
HIRG-MOHE	Pre-clinical assesment of Autologous/Allogenic mesenchymal stem cells derived from various sources.	Noor Hayaty Abu Kasim	RM1562k
FRGS	Attachment, proliferation and differentiation of mesenchymal stem cells on a novel medium chain length - polyhydroxyalkanote scaffolds	Tunku Kamarul Zaman	RM50k
FRGS	Role of epithelial sodium channel (ENAC) in mechanotransduced mesenchymal stem cell (MSC) differentiation	Raja Elina Afzan Raja Ahmad	RM58k
FRGS	Characterization of human amniotic membrane for cartilage tissue engineering	Azura bt Mansor	RM30k
FRGS	The effect of a monolayer and 3d environment on the osteogenic of differentiated bone marrow derived mesenchymal stem cells in vitro	Azhar Mahmood Merican	RM23k
FRGS	Feasibility study of a novel designed hydroxyapatite / PVA-NOCC bilayered scaffold for osteochondral tissue-engineering application	Azlina Amir Abbas	RM50k
FRGS	Human autologous chondrocyte transplantation (HACT) at UMMC		RM29k

FRGS	The use of direct stem cell extraction for immediate cartilage repair as compared to current autologous chondrocyte transplantation (ACT) technique	Azura bt Mansor	RM39k
FRGS	Evaluation of mesenchymal stem cells isolated from dental tissues as an in vitro model for drug screening and toxicity testing	Mariam Abdullah	RM178k
Sciencefund	Development of a robust quantitative chimerism analysis program using various polymorphic genetic markers for patients undergoing haematopoetic stem cell transplantation	Hany Ariffin	RM200k
Sciencefund	Enhancing osteogenic differentiation of mesenchymal stem cells using naturally derived platelet-rich plasma	Azhar Mahmood Merican	RM186k
Sciencefund	The investigation of rotator cuff tendinopathies in human & determining the feasibility of applying tissue engineering methods using autologous fibroblast & MSC for rotator cuff tears	Tunku Kamarul Zaman	RM182k
RUGS	Wound healing potential of mesenchymal stem cells on burn wounds in rats	Alizan Abdul Khalil	RM60k
RUGS	Comparison of TGF-B and TGF-B3 on chondrogenic differentiation of rabbit bone marrow-derived mesenchymal stem cells	Azhar Mahmood Merican	RM209k
RUGS	In vivo trial of bone marrow derived mesenchymal stem cells (MSCS) as a potential source for the repair of degenerated nucleus pulposus	Azlina Amir Abbas	RM3k
RUGS	Proteomic characterisation of human bone marrow and blood derived chondrogenic mesenchymal stem cells: a novel tool for the study of chondrogenesis	Azura bt Mansor	RM75k
RUGS	The effects of in-vitro cultivation of osteogenic-mesenchymal stem cells derived from rabbit bone marrow on different environments	Azura bt Mansor	RM158k
RUGS	Characterisation and identification of specific phenotypic markers of chondrogenic mesenchymal stem cells	Azura bt Mansor	RM220k

RUGS	Phase-II clinical trial assessing safety and efficacy of ex-vivo expanded allogenic mesenchymal stem cells for chronic critical limb ischaemia	Basri Johan Jeet Abdullah	RM100k
RUGS	Investigation of expansion of rabbit bone marrow derived mesenchymal stem cells on microcarrier beads in spin culture	Boo Lily	RM30k
RUGS	In vitro study of the three dimensional effect on the chondrogenesis of bone marrow mesenchymal stem cells	Boo Lily	RM30k
RUGS	Human blood derived mesenchymal stem cells (MSCS): a new potential cell therapy to repair cartilage defects	Chong Pan Pan	RM29k
RUGS	Gene expression profile of adult human peripheral blood derived mesenchymal stem cells stimulated by the TGF-B3 and BFGF	Chong Pan Pan	RM30k
RUGS	Cloning of FLOATS using embryonic stem cells (ESCS) produced from in vivo fertilised embryos	Goh Siew Ying	RM29k
RUGS	Production of cloned caprine embryos through nuclear transfer of embryonic stem cells (NTES) technique	Goh Siew Ying	RM17k
RUGS	Effect of TGF-B1 on the proliferation of bone marrow derived stem cells on a biological hydroxyapatite scaffold	Haris bin Akram	RM7k
RUGS	In vivo study of the effects of intra-articular hyaluronic acid, autologous bone marrow derived mesenchymal stem cells and microfracture in the treatment of articular cartilage defects	Lucy Chan	RM194k
RUGS	Investigation of mini-bioreactor cultivation of mesenchymal stem cells embedded in alginate	Mohamed Razif bin Mohamed Ali	RM72k
RUGS	Optimisation in isolation of the mesenchymal stem cells (MSC) derived from bone marrow for the preclinical studies	Mohamed Razif bin Mohamed Ali	RM158k
RUGS	The effects of static and cyclic tensile loading on human bone marrow derived mesenchymal stem cells in vitro	Nam Hui Yin	RM18k

RUGS	Expression and analysis of DNA and cDNA recombinant clones of adult stem cells in bacterial system	Pouya Hassandarvish	RM15k
RUGS	The effects of monolayer and 3D environment on the osteogenic potential of differentiated bone marrow derived mesenchymal stem cells in vitro	Quan Mun Theng	RM30k
RUGS	Isolation, characterisation and multi-lineage differentiation of post-natal stem cells from dental pulp	Sabri Musa	RM271k
RUGS	In vivo trial of bone marrow derived mesenchymal stem cells (MSCS) as a potential source for the repair of degenerated disc (nucleus pulposus)	Shamsul Iskandar bin Hussein	RM120k
RUGS	Investigation of mini-bioreactor cultivation of human peripheral blood derived mesenchymal stem cells	Tai Cheh Chin	RM74k
RUGS	In vitro study of tenogenic differentiation of mesenchymal stem cells	Tan Sik Loo	RM30k
RUGS	Protein expression profiles analysis of human mesenchymal stem cells (MSCS) and tenogenic MSCS	Tan Sik Loo	RM20k
RUGS	Comparative proteomic analysis of bone marrow derived mesenchymal stem cells with in vitro chondrogenic differentiated mesenchymal stem cells from NZW rabbit	Tay Liang Xin	RM20k
RUGS	In vivo study of the effects of intra-articular hyaluronic acid, autologous bone marrow derived mesenchymal stem cells and microfracture in the treatment of articular cartilage defects	Tunku Kamarul Zaman	RM3k
RUGS	Mesenchymal stem cells for the treatment of muscle injury	Tunku Kamarul Zaman	RM3k
RUGS	Optimisation and tenogenic differentiation in rabbit bone marrow derived mesenchymal stem cells	Tunku Kamarul Zaman	RM209k
RUGS	In vitro study of rabbit chondrogenic mesenchymal stem cells (MSCS) seeding in amniotic scaffold	Tunku Sara bt Tunku Ahmad Yahaya	RM70k

RUGS	Development of an improved polymer-based scaffold for chondrogenesis of rabbit bone marrow derived mesenchymal stem cells	Wee Ai Sze	RM30k
RUGS	The effect of 2-D monolayer and 3-D environment on the chondrogenic potential of bone marrow derived mesenchymal stem cells	Wee Ai Sze	RM25k
RUGS	Mesenchymal stem cells for treatment of muscle injury	Abdul Halim Mokhtar	RM120k
UM Internal	Effect of TGF-B1 on the proliferation rate of bone marrow derived mesenchymal stem cells on a biological hydroxyapatite scaffold	Belinda bt Simon Jingkang Pingguan	RM43k
UM Internal	The effect of intra-articular hyaluronic acid and bone marrow derived mesenchymal stem cell injection in the treatment of osteoarthritis in a rat model	Suhaeb Abdulrazzaq Mahmod	RM5k
L-Oreal Malaysia	Current and innovative area of tissue engineering and manipulation of mesenchymal stem cells for future use as biological therapies for poorly regenerating tissues	Chong Pan Pan	RM20k

Grant	Project	Primary investigator	Quantum*
UPM			
FRGS	Unravelling the role of signalling molecules (WNT) during neural differentiation of mouse embryonic stem cells: a way of generating more neurons in vitro	Norshariza Nordin	RM139k
FRGS	Pluripotential capacity of Stem cells/C-kit positive cells derived from full-term amniotic fluid in vitro	Norshariza Nordin	RM100k
FRGS	Studies on mesenchymal stem cell as a potential cellular therapy for cancer.	Rajesh Ramasamy	RM131k

FRGS	Generation and characterisation of human mesenchymal stem cell from umbilical cord blood: a possible reagent for tissue regeneration and transplantation	Rajesh Ramasamy	RM30k
FRGS	Confining the molecular mechanism of anti-tumourigenic effect exerted by human mesenchymal stem cells via microRNA expression	Rajesh Ramasamy	RM50k
FRGS	Characterization of mammary gland stem cells	Norazizah Shafee	RM257k
FRGS	The identification of lung stem cell –defining brochoalveolar stem cell (BASCS) as the lung stem cell using clonogenic assay in murine lung	Syarilnizam Abdullah	RM100k
Sciencefund	Mechanisms of chemoresistance in breast cancer stem cells	Norazizah Shafee	RM283k
Sciencefund	Generation and characterisation of human mesenchymal stem cells from umbilical cord blood: a possible tool for immunotherapy	Rajesh Ramasamy	RM223k
Sciencefund	Studies on mesenchymal stem cells as a potential cellular therapy for cancer	Rajesh Ramasamy	RM100k
Sciencefund	Gene therapy for ß-thalassemia: development of vector with persistent transgene expression for haematopoietic stem cell gene transfer	Syarilnizam Abdullah	RM100k
Sciencefund	Characterization of mammary gland stem cells	Norazizah bt Shafee	RM270k
eScience	Development of a vector with a persistent transgene expression for haemotopoietic stem cell gene transfer	Syarilnizam Abdullah	RM160k
MTSF	Regulation of cancer stem cell in drug resistant breast cancer by herb-drug treatment	Noorjahan Banu Mohamed Alitheen	RM20k
RUGS	Direct reprogramming of human somatic cells	Nik Mohd Afizan Nik Abd. Rahman	RM30k

Grant	Project	Primary investigator	Quantum*
IMU			
MTSF	Comparing insulin release by insulin-producing cells generated from non-diabetic and diabetic human bone marrow-derived mesenchymal stem cells in vitro	Rebecca Wong Shin Yee	RM30k

Grant	Project	Primary investigator	Quantum*
UTAR			
Sciencefund	Identification of breast and prostate cancer stem cell DNA marker and evaluation of chemotherapeutic drugs on derived cancer stem cells	Alan Ong Han Kiat	RM214k

Grant	Project	Primary investigator	Quantum*
UITM			
Sciencefund	Biomimetic design and fabrication of load bearing tissue scaffolds for stem cells tissue regeneration	Mohammed Rafiq bin Dato' Abdul Kadir	RM249k

Grant	Project	Primary investigator	Quantum*
USM			
ASM (SAGA)	Proliferative activity of cells from remaining dental pulp in response to treatment with dental materials	Siti Fazliah Mohd Noor	RM219k
USM Internal	Evaluation and response of dental stem cells in pulp tissue following pulp capping using CaOH and GIC for restorative procedure using GIC for primary molars.	Siti Fazliah Mohd Noor	RM20k
USM Internal	Dental pulp stem cells response cultured on bioactive nanocomposite scaffold.	Siti Fazliah Mohd Noor	RM40k

Novartis	To study the neural differentiation and characterisation of rat stem cells in striatal brain tissue and bone marrow.	Jafri Malin Abdullah	RM25k
Sanofi	Characterisation of development stage and neural differentiation potential of rat stem cells in striatal brain tissue and bone marrow.	Jafri Malin Abdullah	RM10k
AO Spine	Generation of stem cell-derived inter-vertebral disc specific lineages by co-culturing neural crest stem cells and mesenchymal stem cells	Jafri Malin Abdullah	RM29k
FRGS	A study on the proliferation, apoptosis, and telomerase activity of multi-passage culture of embryonic striatal stem cell under the influence of growth factors.	Hasan bin Jaafar	RM147k
USM Internal	In-vitro analysis of crucial mirnas in stage specific transdifferentiation of mesenchymal stem cells	Hasan bin Jaafar	RM40k
FRGS	Eoigenetic remodelling of mesenchymal stem cell (MSC) by targeting specific microRNAs to induce long term neurogenesis: an in-vitro analysis of MSC plasticity.	Hasan bin Jaafar	RM78k
USM Internal	A study of Tualang honey as an adjuvant to foetal serum in enhancing growth & function limbal and dental stem cells culture.	Tan Jun Jie	RM40k
USM Internal	Cardiac stem cell isolation and culture optimisation for treating infracted heart.	Tan Jun Jie	RM5k
MoHE	Isolation, characterisation and differentiation, potential of mesenchymal stem cell from whole human placenta.	Rosaline bt Hassan	RM88k
USM Internal	Cytotoxic effect of different composite resins on stem cell from human exfoliated deciduous teeth (SHED)	Yanti bt Johari	RM5k
USM Internal	A study of keratinocytes, dermal papilla and stem cell derived from human hair follicle for skin substitute development	Ahmad Sukari bin Halim	RM100k
USM Internal	Identification of differentially expressed Gene/s observed in stem cells derived from extracted human tooth.	Khairani Idah bt Mokhtar	RM38k

USM Internal	Characterisation and assessment the proliferation rate of stem cells from human teeth	Zaihan bt Ariffin	RM35k
USM Internal	Analysis of the correlation between mesenchymal-like stem cells and invasiveness of MDA-MB-231 cells.	Khoo Boon Yin	RM153k
USM Internal	Biocompatability & dentinogenic differentiation potential of stem cells from human exfoliated deciduous teeth & dental pulp stem cells combined with bone morphogenic protein in a scaffold with various dental cements.	Norhayati Luddin	RM245k

Grant	Project	Primary investigator	Quantum*
IMR			
NIH	Derivation of Human Embryonic Stem Cell Lines	Zubaidah Zakaria	RM685k
NIH	Isolation, Expansion and Characterization of Mesenchymal Stem Cell from various for Therapeutic Application	Zubaidah Zakaria	RM642k
NIH	Preclinical Efficacy of MSC Transplantation in an Experimental Model of Liver Cirrhosis	Zubaidah Zakaria	RM240k
NIH	Cultivation of limbal stem cells for clinical application in severe ocular surface disorders	Lim Moon Nian	RM179k
NIH	Propagation and expansion of human embryonic stem cell lines	Puteri Jamilatul Noor Megat Baharuddin	RM250k

** rounded to nearest RM1k*

Note: The information on past and ongoing grants was collected from the research management centres of the respective universities, and is current as of January 2012. UKM has an additional grant for setting up a GMP certified laboratory for approximately RM6.5 million.

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