FOLKETINGET

Udvalget for Videnskab og Teknologi
(2. samling)
UVT alm. del - Bilag 11
Offentligt

Udvalget for Videnskab og Teknologi

Til: Udvalgets medlemmer og stedfortrædere
Dato: 4. december 2007

Henvendelse fra stamcelleforskningsmiljøet om nødvendigheden af en national strategi:

Udvalget har i dag modtaget følgende henvendelse fra stamcelleforskningsmiljøet ved professor Jens Zimmer.
Til henvendelsen på side 2 er der vedhæftet fem efterfølgende bilag:

1. Forslag til danske forskningspolitiske og økonomiske tiltag på stamcelleområdet (2 sider)
2. Teknologisk fremsyn – om bio- og sundhedsteknologi, VTUs rapport fra 2003, udvalgte afsnit.
3. VTUs pressemeddelelse vedr. fremsynsrapporten, 27. marts 2003 (1 side)
4. UK Stem Cell Initiative, Report & Recommendations; Nov. 2005, udvalgte afsnit
5. Department of Health/UK Stem Cell Initiative (5 sider)

Udvalget havde I foråret et møde på Christiansborg med en halv snes stamcelleforskere fra det danske miljø samt en forsker fra Skotland (se evt. 2006-07, UVT, alm. del - bilag 245).

Med venlig hilsen

Finn Skriver Frandsen,
udvalgssekretær

Henvendelsen af 4. december 2007:

Kære Finn,
Jeg går ud fra, at Udvalget for Videnskab og Teknologi nu har konstitueret sig efter valget.

Med det formål at orientere nye medlemmer og andre om

1. nødvendigheden af en national strategi for stamcelleforskning i Danmark, og
2. det oplæg/forslag til en sådan, som jeg sendte til det forrrige udvalg efter vores foretræde i maj,

vedlægger jeg oplægget og det tilknyttede baggrundsmateriale pånyt.
Der henvises i oplægget "DK SC initiativ180907" til de af mig den 3. sept. fremsendte bilag. De refereres til som UVT Alm. del – bilag 245, og det er dette baggrundsmateriale, jeg også vedlægger her.

Jeg håber, at udvalget vil se velvilligt på oplægget, og skaffe midler til et program under f. eks. det strategiske forskningsråd. Strategi-oplægget svarer i sine argumenter og anvisninger helt til det, man har gjort i bl.a. England og Skotland, og som den danske fremsynsrapport fra 2003 lagde op til. I modsætning til f.eks. nano-området er anbefalingerne på stamcelleområdet imidlertid endnu ikke er effektueret.

Med venlig hilsen
Jens Zimmer

Professor, dr. med.
Anatomi & Neurobiologi
Syddansk Universitet
Winsløwparken 21, DK-5000 Odense C
tlf. +45 65503801 (office)
+45 65503800 (secretary)
jzimmer@health.sdu.dk

"Innovation forms the backbone of the knowledge-based economy and stem cell research represents a substantial opportunity for future innovation in the life sciences."
(Første sætning i Excutive Summary (s.5) in Report & Recommendations of The UK Stem Cell Initiative, Nov. 2005; www.advisorybodies.doh.gov.uk/uksci/)

Forslag til danske forskningspolitiske og økonomiske tiltag på stamcelle-området.

Baggrund. Globalt stilles store forventninger til stamceller som udgangspunkt for nye behandlingsformer og special-designede celler til nyudvikling af lægemidler og toksikologisk screening. Kun forskning og innovativ virksomhed på højt plan kan gøre forventningerne til virkelighed. Lande som Storbritannien har som konsekvens heraf, jvf. det indledende citat, etableret *The UK Stem Cell Initiative* (jvf. UVT alm. del – bilag 245), som sammen med regionale initiativer som f.eks. *The Scottish Stem Cell Network*, med substantielle midler støtter forskningsmæssigt, innovativt og kommercielt samarbejde mellem private virksomheder, offentlige institutioner og fonde.

Den britiske rapporters anbefalinger af videnskabelig og økonomisk satsning på stamcelle-området støttes af internationale "business-insight" undersøgelser af udbyttet af denne forskning og dens udnyttelsesområder, jvf. nedenstående tabel.

Produktområder	Produkter & Teknologiudvikling	Tids-horisont 1.produkt	Europa marked Mio $
Stamcellebank og cellelinier Biobank for isolerede primære (donor) celler, stamcellelinier og opformerede specifikke cellelinier til forsknings- og screeningformål med tilknyttet database.	**Produkter:** Kvalitetssikret cellemateriale til fri el. licens-betalt brug i R&D og prækliniske tests. **Teknologiudvikling:** Optimeret kryopræservation. Database med cellekarakteristika (gen-profil, funktionelle markører)	1 - 5 år	75
Kvalitetssikringsredskaber Molekyler, detektionsmetoder og funktionelle testmodeller til identifikation af bestemte celletyper og afprøvning af deres egenskaber.	**Produkter:** Antistoffer, kits for gen-ekspression, signal-stoffer, designmolekyler for interaktion med gener og signalveje. Modificerede cellelinier med reporter-molekyler. **Teknologiudvikling:** Detektionsmetoder for DNA- og proteinekspression. Funktionelle test-modeller for cellers udviklingspotentiale.	2 - 5 år	25
Teknologi til dyrkning af stamceller Udspecialiserede dyrkningsmedier og -materialer, udstyr og protokoller til dyrkning af stamceller i alle faser fra isolering til anvendelse.	**Produkter:** Vækstmedier, signal- og vækstfaktorer, **Teknologiudvikling:** Modulation af dyrkningsoverflader og -medier, procedurer og materialer for såvel masseopformering og klonal opformering af enkeltceller.	2 - 5 år	40
Cellelinier fra stamceller til screening Celle-baserede testsystemer til screening for lægemiddel-kandidater og toksiske stoffer.	**Produkter:** Cellelinier udviklet fra embryonale og vævs-baserede stamceller med egenskaber og reaktionsmønstre som nerveceller og pancreas/lever celler. **Teknologiudvikling:** Udvikling af screenings-relevante, event. gen-modificerede cellelinier med tilhørende set-up for detektion og kvantitering af påvirkning.	2 - 5 år	25
Stamceller til terapi Celler og protokoller for celletransplantation for sikker behandling af patienter	**Produkter:** Stabile, funktionelle celletyper udviklet fra stamceller under GMP forhold, med forudgående "proof of concept" indenfor diabetes og Parkinsons sygdom. **Teknologiudvikling:** GMP behandling af stamceller mhp præklinisk/kliniske forsøg og test af delivery metoder.	3 - 10 år	100
Terapeutisk påvirkning af stamceller Medikamentel stimulation af kroppens egne stamceller mhp øget evne til erstatning af tabte celler.	**Produkter:** Biologisk aktive molekyler som specifikt aktiverer/hæmmer gener el. signalveje i stamceller. **Teknologiudvikling:** *In vivo* test af kandidatmolekyler og -gener fundet *in vitro* (se ovenfor) og udvikling af disse eller derivater deraf som lægemiddel.	3 - 10 år	5.000

Tabel 1: Oversigt over produktområder, produkter og teknologiudvikling, tidshorisont for første produkt, og aktører i produktudviklingen. Det europæiske marked, opgjort for 2005, udgør ca. 25% af verdensmarkedet, der forventes 5-8 doblet i 2010. *Reference: Business Insights Management Report (2006) "Opportunities in Stem Cell Research and Commercialization".*

I Danmark har offentlige og private forskningsgrupper på få år etableret en internationalt anerkendt forskningsaktivitet på stamcelleområdet. Med udgangspunkt i de offentlige og private forskningsgrupper i Dansk Center for Stamcelleforskning (DASC; 2002-07) er der siden 2003 opbygget et landsdækkende, tværdisciplinært samarbejde gennem forskerskolen Danish Stem Cell Research Doctoral School (DASCDOC; 2003-07) (www.dascdoc.dk) med 25 deltagende forskergrupper og over 40 ph.d.-studerende. I samarbejde med den basale, eksperimentelle forskning på området er der ved universitetshospitalerne i Århus-

Ålborg, Odense og København igangsat klinisk-eksperimentelle stamcelleprojekter (udover den etablerede brug af bloddannende stamceller fra knoglemarven), ligesom en kreds af store og små danske virksomheder inden for biomedicin og bio- og nanoteknologi har interesse, produkter og udviklingsaktiviteter indenfor stamcelleområdet.

Ministeriet for Videnskab, Teknologi og Udvikling lod i 2002-03 et ekspertpanel lave et teknologisk fremsyn indenfor bio- og sundhedsteknologi. I rapporten "Teknologisk fremsyn om bio- og sundhedsteknologi" (UVT alm. del – bilag 245), der udkom foråret 2003, er dansk satsning på stamcelleforskning og stamcelle-baseret celleterapi, et af de fire anbefalede satsningsområder, - med samme argumenter som findes i den senere britiske rapport. Siden 2003 er en række af fremsynsrapportens anbefalinger ført ud i livet i form af strategiske forskningsprogrammer med tilskyndet fælles deltagelse af universiteter og erhvervsvirksomheder indenfor f.eks. nano-teknologi, individualiseret medicin m.fl.. Udover at den dansk lovgivning pr. 1. sept. 2003 blev ændret med tilladelse til at udvikle og forske i humane embryonale stamceller, og lovgivningen som helhed derfor er på plads i Danmark for de fleste typer af stamcelleforskning, så er der imidlertid ikke fra forskningsråds- eller politisk hold taget initiativer på stamcelleområdet.

Med henvisning til ovenstående, og med lån fra britiske og skotske initiativer, **foreslås som danske tiltag**, at der:

- etableres et særskilt program for stamcelleforskning og stamcelle-baseret celleterapi i regi af Det strategiske Forskningsråd (som sket for andre områder i fremsynsrapporten).
- etableres en offentlig-privat forskningsplatform til udvikling organspecifikke humane stamcelle-linier til screening af toksikologiske stoffer og lægemidddelkandidater ud fra stamceller. (EU direktivet REACH kræver, at ca. 30.000 eksisterende kemikalier testes inden 2010, samtidig med at brug af dyr skal reduceres).
- afsættes midler til danske stamcelleforskeres samarbejde med UK Stem Cell Bank (Etablering af større central stamcellebank i Danmark er ikke nødvendig, hvis der etableres et formaliseres samarbejde med UK Stem Cell Bank, som er etableret af British MRC og Wellcome Trust for et meget stort beløb).
- afsættes midler til officiel dansk deltagelse i International Stem Cell Forum (ISCF) og dets initiativer. (Hidtil har intet dansk forskningsråd kunnet overtales til at deltage sv.t. de fleste andre lande, som vi sammenligner os med. Dansk Center for Stamcelleforskning deltager som uooficiel observatør. ISCF har p.t. iværksat anden fase af en stor sammenlignende karakterisering af etablerede humane embryonale stamcelle linier).
- etableres nationale Centers of Excellence indenfor basal og anvendt stamcelleforskning (inkl. virksomhedspartnere) med 5-årige grundbevillinger.
- etableres nationale Networks of Excellence med fokus på emne-/sygdomsspecifik klinisk translatorisk stamcelleforskning, inkl. den nødvendige basale stamcelleforskning og teknologi-udvikling. (Networks forventes med tydeliggjort ledelse at integrere partnere fra Centers of Excellence og andre på tværs af landet i emne-/sygdomsbaserede netværk).
- afsættes midler til indretning af laboratorier med GMP certifikat i henhold til nationale og EU direktiver om transplantation af væv og celler. (Adgang til GMP faciliteter er nødvendig i alle faser fra udvikling af celleliner fra humane embryonale stamceller til udvikling af disse til sikre, transplanterbare særlige celletyper).
- som støtte til offentlige dialog om stamcelleforskning og udviklingen af stamcelle-baserede behandlingsformer oprettes af et formidlings- og videncenter, (event. i samfinasiering med interesseret forsknings og undervisningsinstitution og private fonde).
- etableres koordinerende aktiviteter mellem forskningscentre, forskerskole, institutioner og regionale og ministerielle organer, inkl. Sundhedsstyrelsen , og patientorganisationer vedr. stamcelleforskning og -behandling.

(4)

Teknologisk fremsyn om bio- og sundhedsteknologi

Ministeriet for Videnskab
Teknologi og Udvikling

1. Sammenfatning og anbefalinger

Inden for bio- og sundhedsteknologi ser vi i disse år en række teknologiske kvantespring inden for livsforlængelse, forbedring af livskvalitet, forebyggelse og behandling af sygdomme. Helt nye behandlingsformer vil se dagens lys, ligesom vi hver især på helt nye måder vil blive i stand til at følge vor egen helbredstilstand. Alt i alt kan dette give helt nye muligheder både for bedre helbred, men også for et generelt bedre velvære for den enkelte.

Mulighederne og udfordringerne er store, og vi vil næppe kunne "vælge frit på alle hylder". Dette teknologiske fremsyn bidrager til, at samfundets og erhvervslivets knappe ressourcer kan blive investeret, der hvor nytteværdien og effekten er størst - set både i forhold til vækst og velfærd og dermed også i forhold til at imødekomme de kommende års sundhedsmæssige udfordringer.

Ministeriet for Videnskab, Teknologi og Udvikling har derfor igangsat et nationalt teknologisk fremsynsprojekt. Dette teknologiske fremsyn inden for bio- og sundhedsteknologi er et resultat heraf. Det er et ekspertpanel bestående af repræsentanter fra forskning, erhvervsliv og organisationer, som har udarbejdet dette fremsyn for ministeriet. Panelet er sammensat bredt på tværs af sektorer og specialer for at sikre en bred forankring og størst mulig realisme i noget så vanskeligt som et teknologisk fremsyn.

Et teknologisk fremsyn er et redskab for politikere, organisationer og erhvervslivet til prioritering af fremtidige investeringer. Fremsynet skal tjene som grundlag for en bredere offentlig debat samt til kvalificering af dialogen og samarbejdet mellem forskning og offentlige og private virksomheder.

Med afsæt i dette teknologiske fremsyn peger ekspertpanelet på en række anbefalinger inden for fire overordnede indsatsområder. Se tekstboks 1.1.

Grundlaget for anbefalingerne er fire fremtidsscenarier, som panelet har udviklet. De fire scenarier er diskuteret og udarbejdet med udgangspunkt i dagens Danmark og de teknologiske og sundhedsmæssige udviklingstendenser, som forventes at få stor betydning for Danmarks videre udvikling inden for bio- og sundhedsområdet.

De sundhedsmæssige udviklingstendenser præsenteres i det følgende afsnit 1.1, mens de teknologiske udviklingstendenser skitseres i afsnit 1.2. Derpå præsenteres de fire scenarier i afsnit 1.3. Afsnit 1.4 samler op på de gennemgående elementer på tværs af scenarierne, og endelig udfoldes panelets anbefalinger i afsnit 1.5-1.9.

[1] De sundhedsmæssige og teknologiske udviklingstendenser uddybes i henholdsvis bilag A og B.

Tekstboks 1.1: Anbefalinger fra det bio- og sundheds-teknologiske fremsyn

Styrk forskningen

- Styrk den strategiske forskning – f.eks. inden for individuel medicinering
- Solid grundforskning som forudsætning for strategisk forskning
- Kritisk masse i grundforskningsmiljøer
- Løbende evaluering af forskningsgrupper med 5 års interval
- Udbyg samarbejdet mellem universiteter/forskning, hospitaler og virksomheder inden for anvendelsesorienteret forskning – f.eks. medicoteknik og pervasive healthcare
- Nedbryd barrierer for tværfaglig forskning

Oprust uddannelsesområdet

- Flere polyuddannelser som integrerer tekniske og medicinske/biologiske fag
- Reformér meritsystemer – praktisk erfaring skal tælle med
- Livslang tilknytning til universitetet
- Øget internationalisering af uddannelser

Intensivér industriel udnyttelse og innovation

- Gå foran i udviklingen af et effektivt internationalt patentsystem
- Offentlig støtte til F&U i private virksomheder
- Styrk offentligt-privat samarbejde
- Lægemiddelstyrelsen skal være proaktiv i det internationale harmoniseringsarbejde om standarder og krav til skræddersyet medicin
- Bedre orlovsordninger for offentlige forskere
- Individuelle udviklingskontrakter for forskere

Rejs offensiv etisk debat

- Debat om målene for teknologianvendelsen på sundhedsområdet
- Debat om grænserne for privatliv og social retfærdighed
- Debat om ejerskab af patientdata
- Informationskrav til virksomheder og institutioner (etiske regnskaber)
- Debatten skal foregå demokratisk og kontinuerligt

Kilde: Oxford Group, 2003

1.1. Fremtidige sundhedsmæssige udfordringer

På sundhedsområdet står vi over for nogle fremtrædende udfordringer og udviklingstendenser. I fremtiden tegner sig således en række grundlæggende ændringer i det samlede sygdomsbillede, sundhedsvæsenets struktur, behandlerforholdet samt etiske overvejelser. Forhold der alle har spillet en væsentlig rolle i udfoldelsen af scenarierne i dette fremsyn. Se tekstboks 1.2.

Det samlede **sygdomsbillede** synes at ændre sig. Umiddelbart står vi over for den – banale – udfordring, at andelen af ældre stiger, og da gennemsnitsalderen samtidig stiger, vil endnu flere formentlig stille krav til behandling. Yderligere synes sygdomme, der i vid udstrækning er afhængige af livsstil, at blive mere fremherskende i disse år. Stigende problemer med fedme er også en stor udfordring, da det fører til flere karsygdomme, et stigende antal diabetikere og nedslidningsproblemer med bevægeapparatet.

Der er desuden nogle generelle udviklingstendenser i **sundhedsvæsenets struktur** og dynamik man ikke kan se bort fra. Blandt andet er der et manglende udbud af højtuddannet arbejdskraft, omfanget af private forsikringer på sundhedsområdet forventes at stige, og endelig synes udviklingen i sundhedsvæsenets administrative struktur at pege i retning af øget central styring.

Patientens forhold til behandleren, **behandlerforholdet**, ændrer sig også i og med, at patienterne forventer højere service, højere kvalitet og mere individuel tilpasning i behandlingen end tidligere. Samtidig ønsker de et mere sammenhængende behandlingsforløb, men er også villige til at tage mere ansvar for deres eget helbred.

Udviklingen på sundhedsområdet påvirkes på flere områder også af vores **etiske holdninger** til ny teknologi, og der er i det hele taget en lang række etiske konsekvenser af den teknologiske udvikling. Nogle af de etiske holdninger til teknologi, som ofte fremhæves og diskuteres, er bl.a., hvad der er naturligt henholdsvis unaturligt, og hvordan sikkerhed skal prioriteres i forhold til forskellige risici.

Tekstboks 1.2: Danmarks sundhedsmæssige udfordringer

Udviklingen i sygdomsbilledet
- Livsstilsafhængige sygdomme mere udbredte
- Aldrende befolkning
- Miljøskabte sygdomme
- Nye globale bevægelsesmønstre

Sundhedsvæsenets struktur og udgifter
- Øgede sundhedsudgifter
- Problemer med udbudet af højtuddannet arbejdskraft
- Private forsikringer
- Amternes fremtid

De etiske spørgsmål
- Den naturlige udvikling
- Sikkerhed og risiko ved nye teknologier
- Respekten for liv
- Hensyn til menneskers selvbestemmelsesret
- Krav om at være rask

Udviklingen i behandlerforholdet
- Patienternes efterspørgsel ændrer karakter
- Sammenhængende sygdomsbehandling
- Øget ansvar for eget helbred
- Alternative behandlingsmetoder

Kilde: Oxford Group, 2003

1.2. Centrale fremtidige teknologier

Hvorledes vi tackler de sundhedsmæssige udfordringer afhænger i høj grad af, hvorledes vi vælger at håndtere den teknologiske udvikling. De **teknologiske udviklingstendenser** anses for radikale og vil på mange områder bringe de bio- og sundhedsteknologiske muligheder ind i en ny dimension.

Endnu flere teknologier, end det er tilfældet i dag, vil i fremtiden få indflydelse på udbudet af sundhedsydelser. I dette fremsyn har det imidlertid været vigtigt at identificere de bio- og sundhedsteknologier, som vil få særlig afgørende indflydelse på udviklingen og radikalt ændre de muligheder, vi har for at behandle, helbrede og pleje mennesker.

Med udgangspunkt i erfaringerne fra en række internationale bio- og sundheds-teknologiske fremsyn og gennem høringer hos en række fageksperter vurderede panelet, at mulighederne inden for humane genomer og proteomer, stamceller, bio-elektronik og pervasive healthcare netop opfylder et sådant potentiale, og derfor er kernen i dette fremsyn og scenarieudfoldelsen.

Inden for **humane genomer og proteomer** har kortlægningen af det menneskelige DNA banet vejen for helt nye måder at forvalte sygdomme og sundhed på. Der er tale om et paradigmeskift i retning af individualiserede og forebyggende behandlingsformer på grundlag af genetisk disposition, målrettet screening, diagnosticering og innovative medicinske behandlingsmetoder. Perspektiverne er blandt andet screening for genetisk bestemte karakteristika, mere individualiserede og målrettede sygdomsbehandlinger og forbedret bekæmpelse af humane patogener (menneskebårne vira og bakterier).

Stamceller er særlige celler, som har evnen til både at forny sig selv og danne andre typer af celler. Stamceller er på den måde vort legemes eget naturlige reservedelslager af celler. Gennem forskning i stamceller fra det tidlige fosteranlæg og de forskellige væv hos voksne forsøger man i dag at forstå og udnytte legemets naturlige reservedele. Derved åbnes meget spændende perspektiver for udvikling af nye behandlingsformer, hvor stamceller kan bruges til at erstatte syge celler og væv (stamcelle-baseret celleterapi).

Inden for **bio-elektronik** har nyere forskning, i bl.a. cellernes egenskaber og deres samspil med deres omgivelser, åbnet for nye måder at integrere og skabe samspil mellem biologisk materiale og elektroniske systemer. Ved hjælp af nanoteknologi er man blevet i stand til at undersøge og konstruere systemer helt ned på det atomare niveau. Denne teknologi er man så i stand til at kombinere med ny viden om cellernes evne til at fungere som elektriske enheder så som transistorer (elektriske ledere og kontakter) og mere grundlæggende deres evner som analytiske måleredskaber. Bio-elektronik er derfor en meget spændende mulighed for bl.a. det medico-tekniske område gennem udviklingen af elektroniske implantater til f.eks. rehabilitering og biosensorer til monitorering.

Pervasive healthcare vil i fremtiden kunne udnyttes til at give patienter, pårørende og personale bedre adgang til information, når og hvor de har behov for det. Mulighederne inden for sundhedsfremme og behandling i hjemmet – home care – er også mange. Pervasive healthcare kan derfor ses som forbedring af pleje, kommunikation og ressourceudnyttelse og vil således kunne optimere sundhedssektoren på flere områder.

I tekstboks 1.3 listes nogle fremtrædende potentielle anvendelsesmuligheder for de fire teknologiområder:

Tekstboks 1.3: Potentielle anvendelsesmuligheder inden for humane genomer og proteomer, stamceller, bio-elektronik og pervasive healthcare:

Humane genomer og proteomer

Genetisk diagnostik

- Personlig genprofil (genkort)
- Prænatal diagnostik

Forebyggelse

- Identificere sygdomme før de opstår

Individualiseret behandling

- Genterapi og humane forbedringer
- Farmakogenomik (hvordan genetiske faktorer påvirker lægemidlers virkning)

Betydningen af humane patogener

- Forbedret bekæmpelse af vira og bakterier

Stamceller

Stamcelle-baseret celleterapi

- Neurodegenerative sygdomme (Parkinsons, Alzheimers, cerebral iskæmi, dissemineret sklerose)
- Traumatiske hjerne- og rygmarvslidelser
- Diabetes type 1 (insulinproducerende celler)
- Degenerative muskelsygdomme
- Svære leverskader
- Følger efter kræftbehandling

Organdyrkning

- Hud
- Brusk og knoglevæv

Bio-elektronik

Bio-elektronik i nanoskala

- Nano-robotter
- Biologiske computere
- Biosensorer
- Biochips

Elektroniske implantater

- Implantater der kan kommunikere med nerver
- Kunstig nervestimulering
- Kunstige følesanser
- Kunstige organer

Pervasive healthcare

Forbedret udnyttelse og indsamling af data

Forbedrede arbejdsgange for klinisk personale

- Bedre brugerflader
- Mere intelligente systemer

Øget egenomsorg

- Automatisk og mobil monitorering
- Forbedret kommunikation
- Indlæggelse i eget hjem (det virtuelle hospital)

Som sagt vil disse teknologier på mange områder bringe sundhedspleje ind i en helt ny dimension. Et særligt karakteristika ved den teknologiske udvikling er, at disse fire teknologiområder understøtter en individualisering i behandling og pleje, som ikke kendes i dag. Individualiseret medicin, individualiseret pleje gennem computer-teknologi og individuelt tilpassede implantater og organer vil således være et meget centralt element i behandling og pleje i år 2020.

På baggrund af denne skitsering af både revolutionerende bioteknologiske gennembrud og generelle sundhedsmæssige udfordringer i de kommende 10-20 år burde det være klart, at vi i Danmark står over for store politiske valg og strategiske satsninger.

eller RNA, har alle de fordele, som eksisterende vacciner har, men ikke ulemperne. De vil aktivere immunsystemet, men vil ikke føre til infektioner. De vil være billigere, mere stabile, nemmere at opbevare, og kan udvikles til at indeholde adskillige stammer af patogener på en gang.

- **Bedre og mere sikker medicin – ved første forsøg**
  I stedet for en "trial-and-error" metode til at matche patienter og medicin, vil lægerne i et vist omfang kunne analysere en patients genetiske profil og ordinere den bedste tilgængelige terapi og behandling fra starten.
- **Mere præcise metoder til at bestemme doser**
  I dag baseres metoder på at finde frem til rette dosis på alder og vægt. I fremtiden vil man tage udgangspunkt i en patients genetiske kort – og hvor godt kroppen tager imod medicinen og hvor lang tid metaboliseringsprocessen tager. Dette vil maksimere værdien af terapien og mindske risikoen for en overdosis.
- **Avanceret screening for sygdomme**
  Viden om en persons genetiske kode indebærer, at man kan rådgive en given person i at tilpasse eller ændre sin livsstil i en tidlig alder for dermed at undgå eller mindske risikoen for, at personen udvikler genetiske sygdomme. Ligeledes vil viden om en persons risiko for, at udvikle en specifik sygdom muliggøre løbende monitorering, og at behandling sættes ind på det mest passende tidspunkt for at maksimere effekten af en given terapi.

Stamceller

Celler er kroppens byggesten og mindste fungerende enhed. Til at varetage legemets forskellige funktioner findes ca. 300 forskellige slags celler, samlet i væv og organer med forskellige opgaver. Tænk f.eks. på kroppens muskler, hjernen, nyrerne mave-tarmkanalen og leveren. Når celler dør, skal de erstattes af andre for at undgå at nogle af legemets funktioner reduceres eller går tabt. Det er her stamceller er interessante. Stamceller er nemlig særlige celler, som netop har evnen til både at forny sig selv og danne andre typer af celler. Stamceller udgør legemets **naturlige reservedelslager** af celler.

Tekstboks B.2:

Potentielle muligheder inden for stamcelle-teknologi

Stamcelle-baseret celleterapi

- **Neurodegenerative sygdomme (Parkinson's, Alzheimer's, cerebral iskæmi, disseminered sklerose)**
- **Traumatiske hjerne- og rygmarvslidelser**
- **Diabetes type 1 (insulinproducerende celler)**
- **Degenerative muskelsygdomme**
- **Svære leverskader**
- **Følger efter kræftbehandling**

Vævs- og organdyrkning

- **Hud**
- **Brusk og knoglevæv**
- **Ny lever, nyre osv.**

Kilde: Oxford Group, 2003

11

Gennem forskning i stamceller prøver man at forstå og udnytte legemets naturlige reservedele. Det har åbnet meget spændende perspektiver for nye behandlingsformer, hvor stamceller kan bruges til at erstatte syge celler og væv (**stamcelle-baseret celleterapi**).

Hvad er stamceller biologisk set?
Biologisk set dækker betegnelsen stamceller over mange typer af celler. De første rigtige stamceller dannes af den befrugtede ægcelle i løbet af de første dage i form af en klump af datterceller, der hurtigt begynder at varetage forskellige opgaver. Nogle celler hjælper med til at indlejre fosteranlægget i livmoderen og danne fosterhinderne (ydre cellemasse). Andre begynder at danne selve fosteret (indre cellemasse). Det er fra cellerne i den indre cellemasse (de embryonale stamceller), at man under den videre fosterudvikling får dannet alle de ca. 300 forskellige celletyper, som vort legeme er sammensat af. Celler af samme type danner de forskellige væv, f. eks. bindevæv, muskelvæv og nervevæv, og tilsammen danner de forskellige væv legemets forskellige organer, f. eks. lunger, hjerte, lever og hjerne.

Helt fra vævenes første dannelse i fosteret og senere i den nyfødte og voksne organisme findes der et større eller mindre antal af stamceller i vævene. Det er fra disse vævsbestemte eller **"voksne stamceller"**, at der dannes nye celler under den almindelige vækst af fosteret og barnet, ligesom voksne stamceller danner nye celler til erstatning for de celler, der slides ned og dør. Røde blodlegemer lever f. eks i ca. 120 dage, og tarmceller i ca. 7 dage. Når der sker skade på vævene eller organerne ved sygdom eller direkte ødelæggelse, som f. eks. forbrændinger af huden, er det også fra vævenes voksne stamceller, at nye celler til reparation skal komme. Om reparationen (ophelingen) lykkes afhænger på den ene side af skadens størrelse og på den anden side af de voksne stamcellers evne (potentiale) til at danne nye celler, og den er forskellig fra væv til væv (god i huden, meget dårlig i hjernen).

Fra naturens side er de embryonale stamceller altså byggesten og udgangspunkt for alle fosterets forskellige væv og organer. Væksten og fornyelsen af celler i allerede dannede væv og organer, som de findes hos fosteret, barnet og den voksne, sker fra de såkaldte voksne stamceller. Med disse naturlige udgangspunkter er det stamcelleforskningens mål at isolere og opformere embryonale stamceller fra det tidlige fosteranlæg og voksne stamceller fra vævene og derefter udspecialisere dem i bestemte retninger med henblik på erstatning af syge celler og væv, hvor legemets egne stamceller og reparationsevne ikke slår til. Celle- eller vævsterapi kendes allerede fra transplantation af hud til større forbrændinger, blodtransfusioner ved større blodtab, og transplantation af knoglemarvsceller efter kraftig bestråling, som led i cancerbehandling, eller ved sygdomme i knoglemarven. Den nye viden om stamceller i stort set alle væv har sat kraftig fokus på **regenerativ medicin**, som området kaldes, og givet store forhåbninger om brug af stamceller og legemets egne celler i behandlingen af celle- og vævsskader.

En sådan stamcelle-baseret celleterapi vil have sin primære anvendelse i behandlingen af – ofte livstruende eller svært invaliderende - sygdomme, hvor bestemte veldefinerede og gerne med sikkerhed lokaliserede celler er gået til grunde. Ændringer af vævenes indhold af stamceller og stamcellernes egenskaber ved aldring rejser også spørgsmålet, om stamceller kan anvendes i forebyggelse eller egentlig forbedringer af almindelige fysiologiske forandringer. Som udgangspunkt er det dog i forhold til udviklingen af helt nye behandlinger af en lang række svære eller kroniske sygdomme, at potentialet i stamcelleforskningen og de deraf afledte celleterapier ligger.

Behovet for ny viden
Stamcelleforskningen er endnu i en tidlig udviklingsfase. Der er således stadig megen ny viden, der skal skaffes og afprøves før stamceller vil finde almen anvendelse i sygdomsbehandling. Feltet er dog både herhjemme og internationalt i rivende udvikling med fokus på forhold som:

- Hvordan man kan isolere stamceller
- Hvordan man kan opformere cellerne med fastholdelse af deres potentialer
- Hvordan man kan opbevare cellerne i laboratoriet og til klinisk brug (biobanker)
- Hvordan man kan styre udviklingen af de forskellige ønskede celletyper i laboratoriet og samtidig tilvejebringe det nødvendige antal til forskning og behandling
- Hvordan man får etableret sikre testmodeller til afprøvning af cellernes funktionelle egenskaber, herunder også selve behandlingen med cellerne (transplantation, hvor, hvordan)
- Hvordan man sikrer, at behandlingen i sig selv ikke udgør en helbredsmæssig risiko

Valg af typer af stamceller?
Er embryonale eller voksne stamceller det bedste udgangspunkt for en stamcelle-baseret celleterapi? Ingen kender svaret i dag. Et ordentligt svar kan kun gives, når vi ved mere om begge typer af celler, og derefter vil svaret sandsynligvis afhænge af den sygdom og celleterapi, det drejer sig om.

De **embryonale stamceller** har principielt det største og bredeste potentiale. Gennem nogle få generationer af datterceller er disse celler fra det tidlige fosteranlæg jo netop ophav til alle organismens celletyper og dermed også de forskellige typer af voksne stamceller. På grund af den direkte kobling af de embryonale stamceller til det tidlige fosteranlæg er der etisk begrundede indvendinger mod brugen af disse celler, og det skal bemærkes, at det indtil videre ikke er tilladt at udvikle humane embryonale stamceller i Danmark. I stedet forskes i voksne stamceller og embryonale stamceller fra bl.a. mus og gris. Et andet uafklaret forhold er spørgsmålet om immunologisk forligelighed mellem modtageren (værten) og de transplanterede celler ved celleterapi baseret på embryonale stamceller.

Voksne stamceller er en anden kilde til celler til celleterapi. Voksne stamceller findes således i varierende antal i de forskellige væv fra det tidspunkt, hvor vævene og organerne er begyndt at dannes, dvs. i 6-8 uger gamle fostre og videre frem hos børn og voksne. Stamceller fra et givet væv, f. eks. umodent hjernevæv fra ca. 8 uge gamle, aborterede fostre, er på dette tidspunkt udspecialiseret i retning af dannelsen af nerveceller og gliaceller (støtteceller) i hjernen og burde således i princippet være nemmere at styre frem mod f. eks. dopamin-producerende nerveceller til behandling af Parkinsons sygdom. Både her og for leverceller, hjertemuskelceller, almindelige muskelceller og knogle- og bruskdannende celler har forskningen gjort fremskridt, men resultaterne er stadig på det eksperimentelle plan. For visse celletyper, som f. eks. de insulin-producerende celler i bugspytkirtlen, synes det svært at isolere og opformere stamcellerne fra selve vævene. Det er også klart, at en person med en given sygdom, hvor en bestemt celletype er ramt (sukkersyge, Parkinsons sygdom og genetiske sygdomme generelt) ikke kan være donor af voksne stamceller (fra det syge væv) til sig selv.

Et påtrængende spørgsmål er, om der blandt de voksne stamceller i vævene findes et meget lille antal stamceller med samme evne som embryonale stamceller til at danne

nye celler fra andre væv, eller om voksne stamceller kan bringes til at skifte linje og danne andre celletyper ved såkaldt **transdifferentiering**. Der er allerede offentliggjort en opdagelse af en tilsyneladende meget umoden og potent celletype i bl.a. bindevævet i knoglemarven. Et endeligt bevis herfor vil gøre voksne stamceller særdeles attraktive som udgangspunkt for udviklingen af flere typer af andre stamceller. Som kilde til voksne stamceller inden for især blod- og bindevævsområdet skal også nævnes navlestrengsblod.

Dannelse af stamceller gennem kernetransplantation
Ved overførsel (transplantation) af en cellekerne fra eksempelvis en voksen bindevævscelle til en befrugtet ægcelle, hvis egen kerne samtidig fjernes, er det muligt ved særlig behandling at reaktivere gen-materialet (arvemassen) i den voksne cellekerne. Således reprogrammeret erstatter denne cellekerne derefter ægcellens kerne. I den videre udvikling af f. eks. et fosteranlæg fra den kernetransplanterede celle vil det være den oprindelige bindevævscelles arvemasse, der bestemmer og videregives til dattercellerne.

Hvis en sådan kernetransplanteret ægcelle fik lov at udvikle sig i en livmoder til et rigtigt foster, ville der være tale om en (reproduktiv) klon, som f. eks. fåret Dolly. Her kom den transplanterede kerne fra en yvercelle fra et voksent får. Kloning af mennesker er forbudt i Danmark, ligesom i mange andre lande. Det er heller ikke på nuværende tidspunkt tilladt herhjemme at lade klonede fostre fra husdyr komme til fødsel.

Kernetransplantation med henblik på at frembringe embryonale stamceller fra det helt tidlige fosteranlægs indre celle masse (terapeutisk kloning) er imidlertid etisk kontroversielt, men åbner op for nogle nye anvendelsesmuligheder. Embryonale stamceller frembragt på denne måde vil nemlig kunne udstyres med en arvemasse som gør, at cellerne i højere grad end ellers er forligeligelige med en aktuel modtager eller en større gruppe af lignende modtagere. De **kernetransplanterede embryonale stamceller** udtages og opdyrkes fra den indre cellemasse af helt tidlige fosteranlæg på samme måde som de regulære embryonale stamceller (se ovenfor), og må på forhånd anses for at have de samme generelle egenskaber og anvendelsesområder som andre embryonale stamceller. De begrænsede resultater indenfor reproduktiv kloning på dyr med nedsat levedygtighed i fosterperioden og efter fødslen, hvor en række celletyper har spillet sammen i længere tid, kompromitterer således ikke på forhånd de biologiske egenskaber af de enkelte cellelinjer, der kan udvikles fra kernetransplanterede embryonale stamceller. Sådanne cellelinjer skal som alle nuværende og kommende humane cellelinjer grundigt afprøves inden terapeutisk brug.

Fremtidige anvendelsesmuligheder
Stamceller rummer potentielt set mange muligheder for behandling af forskellige sygdomme og erstatning af tabte eller defekte celler. Med afsæt i den aktuelle viden om stamceller skal der nedenfor peges på potentielle anvendelsesmuligheder indenfor den regenerative medicin omfattende såvel celleterapi og udvikling af nye organer. En væsentlig kilde til stamceller kan vise sig at være stamcellebanker, hvor eksempelvis det enkelte individ kan gemme egne stamceller.

På flere områder er der som nævnt nogen vej endnu, før forskningen kan komme med afgørende viden til at stamcellerne kan anvendes i behandling, men måske også til egentlig forebyggelse eller forbedringer.

Stamcelle-baseret celleterapi
Perspektiverne for medicinsk behandling ved hjælp af eksempelvis transplantation af stamceller eller mere specialiserede celler udviklet fra stamceller synes meget lovende. Den grundlæggende ide er, at sygdomme som involverer ødelagte eller nedbrudte celler kan afhjælpes eller kureres ved at indføre nye stamceller i det pågældende organ eller ved at tilføre særlige vækstfaktorer, som beskytter og stimulerer vævets stamceller til dannelse af nye celler. Denne form for celleterapi er velkendt og anvendes f. eks., når stamceller fra knoglemarven benyttes til genetablering af dannelsen af blodets celler efter kræftbehandlinger, f.eks. leukæmi, ligesom erythopoetin (EPO) gennem tilførslen stimulerer de bloddannende stamceller i knoglemarven.

På internationalt plan er der med transplantation af umodent hjernevæv fra aborterede fostre til Parkinson patienter og indledningsvis også patienter med Chorea Huntington ført bevis for det behandlingsmæssige princip ("proof of concept"), ligesom der er fundet normalisering af blodsukkerregulering ved transplantation af insulin-producerende celler til patienter med type 1 diabetes. I relation hertil foregår der i Danmark frontforskning inden for behandling af type 1 diabetes, hvor eksperimentelle resultater tyder på, at embryonale stamceller kan have et helt særligt potentiale. Lignende forskning foregår inden for udviklingen af stamceller og cellelinier til brug i celleterapeutisk behandling af Parkinson patienter, og inden for knogle-bindevævsområdet.

Stamcelle-baseret organdyrkning
En af visionerne omkring stamceller er, med stamceller som grundlag, at udvikle hele, funktionsdygtige organer egnet til transplantation. Visionerne har indtil videre taget afsæt i "dyrkning" af nye organer og organdele ud fra stamceller fra voksne individer.

I øjeblikket synes forskerne at være kommet ganske langt med at isolere stamceller og delvist uddifferentierede celler fra væv og fra disse celler at opdyrke forskellige vævskomponenter til nye organer. Det er således lykkedes at etablere organlignende vævskulturer af menneskelever, menneskeblære, hud og ledbrusk. Konkrete transplantationsforsøg af fremdyrket vævs- og organmateriale til mennesker synes på det grundlag nært forestående. Hensigten er bl.a. at frembringe ny hud til at dække større defekter over brandsår eller traumatiske beskadigelser, stykker af blærevæg til dækning af defekter efter canceroperationer og strålebehandling eller defekter i selve udviklingen af blære og urinveje, erstatning af levervæv efter svære traumer, forgiftninger og virusinfektioner, samt erstatning af brusk- og knogledefekter i led og i knogler med dårlig opheling. Når det gælder tilsvarende vævs- og organmateriale for dyreorganer er man nået længere med de funktionelle forsøg. Det skyldes en naturlig bredere adgang til forsøg på dyr end på mennesker, og at organerne generelt er mindre og ofte mindre komplicerede hos dyr, ligesom der er biologiske forskelle i vævenes regenerationsevne mellem arterne. Regeneration af nervebaner efter transplantation af øjenanlæg lader sig således indtil nu kun gøre på frøer og fisk, men ikke pattedyr.

Metoden til dyrkning af væv eller hele organer ud fra stamceller består i at isolere de pågældende stamceller fra vævene, opformere dem og derefter med forskellige kombinationer af stoffer eller gennem vekselvirkning med andre celler at få dem til at udvikle sig til den type celle, man har brug for. Rent praktisk er der udviklet en metode, hvor de dyrkede stamceller bliver placeret rundt omkring på et kunstigt 'skelet' eller 'stillads' af nedbrydeligt materiale. Stilladset bevirker, at det nye organ tager den ønskede form, og at de forskellige celletyper kan integreres med hinanden, hvorefter stilladset med tiden nedbrydes af sig selv.

En væsentlig fremtidig udfordring inden for organdyrkningsvidenskaben er at udvikle de rette materialer til opbygning af "stilladserne", hvor forudsætningerne bl.a. er lighed med organisk materiale i overflade og formbarhed samt evne til nedbrydelighed.

Stamcellebanker og biobanker

Adgang til tilstrækkeligt stamcelle-materiale og velkarakteriserede stamcelle-baserede cellelinjer er en afgørende faktor for en bredere anvendelse af stamceller til behandling. Adgang til embryonale stamceller fra de tidlige fosteranlæg er relativt begrænset og behæftet med etiske overvejelser. Adgang til "voksne" stamceller i væv fra aborterede fostre er allerede reguleret herhjemme, men vil til en hver tid være afhængig af antallet af abortsøgende og deres samtykke. Stamceller fra navlestrengsblod giver en bredere ressourcebase i hvert fald inden for blod- og bindevævsdannende stamceller, men stiller også krav til systematisk indsamling og opbevaring. Voksne stamceller fra det enkelte individ er med samtykke i princippet frit tilgængelige, og metoderne til at isolere og opformere disse celler fra forskellige væv er under kraftig udvikling. For visse typer af væv, såsom hjernevæv, er det dog urealistisk at forestille sig, at celler kan erhverves fra personer i levende live i andet end sporadisk omfang.

Ved at etablere og samle stamceller i større "stamcellebanker" vil man både kunne gemme og akkumulere stadig større mængder af stamceller, etablere en ressource- og vidensbank til hjælp til den videre forskningsmæssige karakterisering og videreudvikle de stamcellelinjer, som leveres til "stamcellebanken". Teknisk synes der ikke at være noget problem i at opbevare stamceller i nedfrosset tilstand. Teknikken er almindelig kendt og anvendes bredt for disse og andre tilsvarende celler. Spørgsmålet er mere efter hvilke kriterier stamceller skal "sættes" i bankerne, og hvem der har adgang til at "hæve" en eller flere prøver af stamceller. Generelt kan man sige, at oprettelsen af en "stamcellebank" uden tilknyttet forskningsmulighed på de opbevarede celler og cellelinjer ikke har stor mening, da kun forskningen i stamceller kan påvise og sikre deres potentiale, – og dermed deres senere anvendelse. Opbevaring af stamceller fra enkeltpersoner i en stamcellebank er kun at betragte som en "forsikring", hvis der samtidig forskes i cellerne og udvikles behandlingsmetoder til deres anvendelse.

Private stamcellebanker

Som "gave" til sit nyfødte barn kan man allerede nu oprette en konto i en stamcellebank, hvor barnets navlestrengsblod opbevares til eventuel senere brug. Navlestrengsblod er således en vigtig kilde til stamceller, som ikke blot matcher det enkelte individ, men det rummer også færre etiske problemer end anvendelse af embryonale stamceller fra det tidlige fosteranlæg.

I USA findes flere specialiserede navlestrengsbanker, og i 1997 blev en navlestrengsbank åbnet i Tyskland. Den tyske bank er godkendt af de tyske sundhedsmyndigheder. I Danmark er der ingen private stamcellebanker, men et privat firma har indtil for nylig tilbudt at modtage navlestrengsblod fra danske børn og arrangere, at det blev opbevaret i den tyske stamcellebank. Denne ydelse blev tilbudt på rent kommercielle vilkår, og det kostede ca. kr. 15.000 for opbevaring af navlestrengsblod i 20 år.

Offentlige stamcellebanker

Den første egentlige offentlige stamcellebank bliver etableret i Storbritannien i september 2002, se tekstboks B.3. Det umiddelbare perspektiv for stamcellebanken er at indsamle og vedligeholde stamceller og stamcellelinjer til forskningsmæssigt brug. Stamcellebanken skal tillige ses i lyset af, at Storbritannien har ændret sin lovgivning om brug af stamceller.

Tekstboks B.3: Europas første stamcellebank i UK

I september 2002 annonceredes åbningen af den første stamcellebank i Storbritannien, som skal være en enkeltstående institution for opbevaring af alle stamcellelinjer udviklet i Storbritannien. Banken skal administreres af det uafhængige National Institute for Biological Standards and Control.

På sigt åbner den offentlige stamcellebank også op for, at alle - og ikke kun de, som har været forudseende - kan behandles med stamceller fra banken. Med andre ord er der her taget både et teknisk, men også et bredere sundhedsmæssigt initiativ.

I Danmark findes Biologisk Bank Danmark med tilknytning til Laboratorium for Stamcelleforskning ved Aalborg Universitet og associeret med Dansk Center for Stamcelleforskning. Banken startede som en forsøgsordning under navnet Biologisk Bank Fredericia, og der arbejdes nu på en aktivering af "banken", sandsynligvis som en forsøgsordning i regi af Nordjyllands Amt og Aalborg Universitet.

Bio-elektronik

Bio-elektronik er forskning i grænsefladerne mellem menneske og maskine eller mere præcist, mellem biologisk materiale og elektroniske systemer. Bio-elektronik kan opfattes som en fusion af to specialer:

- Elektronik (specielt mikro- eller nano-elektronik)
- Biomolekylære, eller biocellulære væv

Tekstboks B.4: Potentielle muligheder inden for bio-elektronik

Bio-elektronik i nanoskala
- **Nano-robotter**
- **Biologiske computere**
- **Biosensorer**
- **Biochips**

Elektroniske implantater
- **Implantater der kan kommunikere med nerver**
- **Kunstig nervestimulering**
- **Kunstige følesanser**
- **Kunstige organer**

Kilde: Oxford Group, 2003

17

Department of Health

Government response to the UK Stem Cell Initiative report and recommendations

Published: 2 December 2005

The Government warmly welcomes the report of the UK Stem Cell Initiative Panel, chaired by Sir John Pattison. The report provides a comprehensive overview of the status of stem cell research in the UK and overseas: a clear vision for future endeavour with indicative costs for a strategy to maintain the UK's position as a world leader in basic research. It also provides a 'road map' to translate basic research in stem cells into new therapies to benefit patients.

The Government is particularly pleased that the report has acknowledged the appropriateness of the UK system of regulatory oversight of embryo research and the investment that has been made to date across research funding, infrastructure, people and support for private investment.

In 2004-05 the Government invested around £25m in basic research and associated support such as the UK Stem Cell Bank. The Government accepts the recommendations in the UKSCI report. As a result of taking forward these recommendations, total public sector funding for stem cell research over the two year period 2006-07 and 2007-08 will be up to £100 million, representing additional investment of around £50 million. In particular, the Government will:

- work towards the establishment of a public-private consortium to use stem cells to enhance drug discovery and development (Recommendation 1);
- provide resources to redevelop and maintain the UK Stem Cell Bank (Recommendation 2);
- increase funding to support basic stem cell research and Centres of Excellence, cell production facilities and clinical research in the NHS (Recommendations 3,4,5,7);
- support the joint UK Stem Cell Foundation / Medical Research Council (MRC) initiative to support translational stem cell research and clinical trials (Recommendation 6);
- continue to ensure regulation of stem cell research is flexible and appropriate and makes use of proven expertise such as in the Gene Therapy Advisory Committee (GTAC) to review novel stem cell clinical trials (Recommendation 8), and
- build on the close links established under the UK Stem Cell Initiative to provide effective forums to improve collaboration around research funding, cross-fertilisation between scientists, technical experts and private industry and provide a platform for a sustained programme of public dialogue on stem cell research over the next decade (Recommendations 9-11).

Over the next decade, the Government will take careful note of the recommendations to inform the development of its investment and regulatory strategy in this area in future spending reviews.

The Government is extremely grateful to Sir John Pattison, the members of the UK Stem Cell Initiative Panel, UK scientists and entrepreneurs as well as international advisors for providing such a thorough and considered report and for the vision of improved knowledge about the causes of, and therapies for, devastating diseases and medical conditions.

Detailed response to specific recommendations

Recommendation 1: The UK Government should establish a public-private partnership to develop predictive toxicology tools for stem cell lines.

(18)

The Government recognises the importance of this suggestion to establish a public-private consortium to develop a wide range of safe and effective medicines for patients using stem cell technology. We also recognise that such a consortium would undoubtedly extend the stem cell research base within the UK and fortify our global position in this area.

The Technology Programme is already supporting a £1.75m project that is developing a high-throughput screen for small molecule drugs using stem cells. This platform could also be used for toxicology screening. The MRC is supporting research at the MRC Toxicology Unit in Leicester looking at the cellular response to chemicals that will also be relevant to the use of stem cells in predictive toxicology. They have also initiated meetings with pharmaceutical companies to explore the use of stem cells in toxicology and drug development, to discuss possible areas of common interest and possible collaboration.

The Department of Health and DTI will consult widely with the pharmaceutical and biotechnology sectors over the next few months to determine the feasibility of this proposition, reporting in Spring 2006. Should this proposal receive significant support from the private sector, the Government will establish such a consortium with the necessary Government contribution to management and research costs (estimated as up to £0.7m in 2006-07 and £1.3m in 2007-08). DTI will build on its support for collaborative research in stem cell technology through the November 2005 competition of the Technology Programme, and will consider whether further support is justified towards the end of the current projects.

Recommendation 2: The UK Stem Cell Bank should be consolidated in new permanent facilities adjacent to its current site and its operational and development costs should be secured for the next decade.

The Government recognises the importance of the UK Stem Cell Bank to provide a world-leading resource of well-characterised and ethically sourced stem cell lines. The MRC will therefore invest between £5m and £6m to redevelop the Stem Cell Bank, and has committed £1m per annum over 2006-07 and 2007-08 towards its operational costs. The Biotechnology and Biological Sciences Research Council (BBSRC) has committed £0.2m per annum over the same period.

Recommendation 3: The Research Councils should monitor the emergence of Centres of Excellence in stem cell research, designate them as such and strengthen them with core funding.

The MRC has already designated two Centres of Excellence in Stem Cell Research and is considering proposals for a third. Others will be considered as part of the regular five yearly reviews of Institutes and Grants. BBSRC also invests in existing Centres and clusters and is actively inviting larger, longer-term, multidisciplinary grant applications from researchers including those involved in stem cell research.

Recommendation 4: Research Councils and private sector funding bodies should support the development of stem cell therapy production units at UK Centres of Excellence in stem cell research.

The Government fully recognises the need to develop facilities for the production of stem cells. The Report acknowledges the additional investment, totalling £4.2m in 2005-06 for the NHS Blood and Transplant Authority to support the storage and use of bone marrow and peripheral blood stem cells which we continue to support.

DTI is also anticipating the need for developments in stem cell technology for research and clinical applications through the Technology Programme. Regenerative Medicine Technologies is a priority in the Autumn 2005 Technology Programme competition with an indicative budget of £10m of DTI funding. Additional funding may come from the Research Councils and a proportion of the costs of each project will come from the industrial participants. There are a number of technical focus areas for the competition that are directly relevant to stem cell technology and to underpinning and related technologies such as advanced biomaterials for tissue scaffolds. The proposed research may include early stage clinical trials. Bioprocessing of tissue engineering products was a focus area in the Spring 2005 competition. This is in addition to the earlier stem cell technology projects now underway from the Spring 2004 Technology Programme competition, which will receive an estimated £1.6m and £1.2m from their overall grants in 2006-07 and 2007-08, respectively. Measurement standards are also important in the development of all new technology areas, DTI's Measurements for Emerging Technologies programme has two projects looking at metrological issues in support of stem cell research. The projects will receive £1.2m of DTI funding over the life of the current programme (2005-2008).

BBSRC has recently launched the Bioprocessing Industry Research Club (BRIC) call with a BBSRC budget of

£8.7m. While not all projects will directly involve stem cells, they could provide vital underpinning work to the future scale-up of stem cell culture and distribution.

Recommendation 5: The Government and Research Councils should strengthen the levels of funding for basic stem cell research over the next decade.

The Research Councils are aiming to increase their commitment to basic research in stem cells, including centres of excellence, to reach at least £24m by 2007-08. The precise figures will depend on the quality of applications submitted to the Research Councils.

Recommendation 6: The Government should provide funding for clinical and translational stem cell research over the next decade at a level matching that raised by the UK Stem Cell Foundation (UKSCF), up to a maximum of £10M per annum, and administer it via a UKSCF/Medical Research Council collaboration.

The MRC and the Stem Cell Foundation have set up a joint mechanism for the scientific evaluation of clinical and translational proposals and are currently considering a proposal worth £2m. In 2006-07 and 2007-08 they will consider additional proposals as they arise and contribute up to £1m per annum to joint projects with the Foundation. If this proves to be a successful way forward, the Government will seek to extend the collaboration to enable the MRC to jointly fund translational and clinical stem cell research projects with the UK Stem Cell Foundation.

In addition, Scottish Enterprise has established a Stem Cell Translational Investment Fund of £5m for collaborative projects in Scotland with other organisations including the UK Stem Cell Foundation.

Recommendation 7: The Department of Health must ensure that the promised increase in R&D resources is forthcoming and furthermore, that the full NHS costs of stem cell clinical research trials within the NHS are supported with extra funding from each Spending Review over the next decade to match the increase in research grants and activity.

The Government fully intends to meet its commitment to provide an additional £100 million for NHS R&D compared with 2003-04 levels. This new investment is underpinning the activities of the UK Clinical Research Collaboration (UKCRC) and the Government will ensure that the excellent work begun by the UKCRC continues to transform the clinical research environment in the UK.

It is also the Government's intention to meet eligible service support costs of clinical stem cell research within the NHS. Additional funding beyond the current Spending Review period will need to be considered in future Spending Reviews alongside other priorities.

Recommendation 8: The Government should continue to ensure that regulation of stem cell research is risk-based and proportionate and does not stifle the development of the full range of safe and effective new cell therapies for the benefit of patients. In particular,
(i) the Department of Health should establish a specialised research ethics committee for stem cell clinical research;
(ii) the Government should clarify the regulatory requirements for the use of animals and animal cells in human stem cell research; &
(iii) for the in vitro use of embryonic stem cell lines, researchers should be registered with, and submit an annual research summary report to, the UK Stem Cell Bank.

The Department of Health has overall responsibility in this policy area and will continue to ensure that regulation of stem cell research is flexible, proportionate, accountable, consistent, transparent and targeted. They will work closely with the DTI, Medicines and Healthcare products Regulatory Agency (MHRA), patient groups, the public and the commercial sector to maintain the best possible environment for stem cell research and to facilitate the development of safe and effective therapies for patients. The Department of Health will also continue to work with our European partners to ensure that current and future EU regulatory measures are based on sound science and help to deliver the targets set out in the EU Strategy for the Life Sciences and Biotechnology.

As part of its broader review of the Human Fertilisation and Embryology Act 1990, the Government invited views on whether the law should permit the creation of human-animal hybrid or chimera embryos for research purposes only (subject to a limit of 14 days culture in vitro after which the embryos would have to be destroyed). This followed a recommendation of the House of Commons Science and Technology Committee, that new legislation should define the nature of hybrids and chimeras, make their creation legal

for research purposes, and prohibit their implantation in a woman.

The Home Office is responsible for providing guidance on the application of the Animal (Scientific Procedures) Act to experimental and other scientific uses of animals in work involving human and animal stem cells. The intention is to ensure that researchers are clear about their duties and responsibilities and that unnecessary delay is avoided. The Home Office is also committed to working with relevant stakeholders via the improved collaborative mechanisms described below.

Ethical oversight

The Government has taken careful note of the Report's recommendation for a specialist research ethics committee to consider stem cell clinical trials of embryonic stem cells and other pioneering trials of stem cells introduced into different organs or locations. The report notes that the House of Lords Select Committee Report on Stem Cells recommended extending the remit of the Gene Therapy Advisory Committee (GTAC), but eventually recommended a separate research ethics committee. Whilst the Government shares the desire to ensure patients safety, we do not anticipate a large number of novel clinical trials involving stem cells in the next two to three years. Therefore, for the time being we believe that the expertise developed by GTAC over the last decade would lend itself to the specialist ethics review of stem cell trials in the manner recommended by the Report. Some stem cell clinical trials will already fall under GTAC's remit, and the Government will therefore ask them to undertake the ethical oversight of other relevant stem cell clinical trials and to act as a source of expert advice to researchers and other research ethics committees. The appropriate route for ethical oversight will be kept under review. In particular, the Department of Health is making further improvements in the NHS ethical review process and foresees a smaller number of better-trained research ethics committees. Increasingly, the experience derived by GTAC's review of these clinical trials will be valuable to researchers and other NHS research ethics committees.

Recommendation 9: The UK Clinical Research Collaboration should help to
(i) coordinate organisations supporting stem cell research, including all of the relevant Research Councils and the UK Stem Cell Foundation and
(ii) ensure that the National Health Service is optimally engaged in this area.

Recommendation 10: The Government should allocate additional funding to establish The UK Stem Cell Cooperative, to maximise the cross-fertilisation between those involved in the sub-disciplines of UK stem cell research.

The Government recognises the importance of co-ordination between funders, researchers, charities, the private sector and Government Departments. The UK Clinical Research Collaboration is a model for how this should work. The UK Stem Cell Initiative has proved to be an effective means of engaging a wide cross section of those active in stem cell research and we propose that these links should continue and be strengthened to help to implement the recommendations and deliver the vision in the report. The MRC will lead discussions on how best to take this forward, possibly through a revitalised Stem Cell Funders Forum. They will consult a wide range of stakeholders including existing stem cell networks and wider UKSCI partners.

The Research Councils are also supporting workshops and conferences to encourage the sharing of ideas and scientific collaborations. The recent joint BBSRC/EPSRC initiative in Stem Cell Science and Engineering required formal collaboration between stem cell biologists and engineers and/or physical scientists. Sixteen new collaborative projects have been funded under this initiative, with a total funding commitment of approximately £6m.

Recommendation 11: The Research Councils, charitable funding bodies, and Government Departments should develop a sustained and coordinated programme of public dialogue on stem cell research over the next decade.

The Government accepts this recommendation. Government Departments will work with the private charity sector to develop a sustained programme of public dialogue on stem cell research. We will use our dialogue with the public to inform our policy work on any further development of the regulatory system of oversight of UK stem cell research. We believe that it will be vital for the public to have confidence in stem cell research if we are to see the successful development of stem cell therapy. The Research Councils and the Office for Science and Technology's Sciencewise programme will take this recommendation forward.

Related Links

UK Stem Cell Initiative (opens new window)

Pressemeddelelse

FOLKETINGET

Markante muligheder og udfordringer med ny bio- og sundhedsteknologi

27. marts 2003

Ministeriet for Videnskab, Teknologi og Udvikling
Bredgade 43
1260 København K
Telefon 3392 9700
Telefax 3332 3501
E-post vtu@vtu.dk
Netsted www.vtu.dk
CVR-nr. 1680 5408

En massiv teknologisk udvikling inden for bio-sundhedsområdet vil i de kommende år stille det danske samfund og i særlig grad sundhedsvæsenet, medico-virksomhederne og borgerne over for en lang række udfordringer. Det viser et netop offentliggjort teknologisk fremsyn om bio-sundhedsområdet.

Nye, individuelle forebyggelses- og behandlingstillbud samt "indlæggelse" i hjemmet med fjernovervågning vil forandre sundhedsplejen og forholdet mellem behandler og patient. Teknologien vil give nye muligheder, men også udfordre samfundets og borgernes grundlæggende etiske holdninger og værdier.

- Danmark har et stærkt udgangspunkt inden for bio-sundhedsområdet. Gode forskningsmiljøer, en innovativ medico-teknisk industri og et traditionelt godt samarbejde mellem det offentlige sundhedsvæsen og bioteknologiske firmaer, siger videnskabsminister Helge Sander.

- Det teknologiske fremsyn beskriver, hvad der teknologisk "rør" sig inden for bio-sundhedsområdet. Dermed har vi et godt grundlag for at tage de nødvendige initiativer, som på en etisk forsvarlig måde både kan sikre mest mulig sundhed til borgerne for pengene og en styrkelse af danske erhvervsmuligheder.

Kortlægningen af det menneskelige genom, forskningen i stamceller og proteinernes funktioner samt anvendelsen af it og nanoteknologi inden for bio-sundhedsområdet er nogle af de markante forskningsområder og teknologiske udviklingstendenser, der vil få afgørende betydning i de kommende år.

Det teknologiske fremsyn er udarbejdet af et bredt sammensat ekspertpanel med direktør Eva Steiness fra Zealand Pharma i spidsen. Udover at skitsere mulige fremtidsscenarier år 2020 giver panelet en række anbefalinger, herunder at styrke det offentlig-private samspil, it-anvendelsen og forskeruddannelsen inden for bio-sundhedssektoren samt sikre tværgående uddannelsestilbud, som kan bygge bro mellem andre fagområder, eks. de tekniske, og sundhedsuddannelserne.

Helge Sander deltager sammen med indenrigs- og sundhedsminister Lars Løkke Rasmussen den 15. maj i en bio-sundheds-konference i Symbion i København.

Rapporten og info om konferencen kan hentes på www.teknologiskfremsyn.dk eller ved henvendelse til Helle Lundberg Erlandsen, tlf. 7226 5512, hle@vtu.dk.

23

UK Stem Cell Initiative

Report & Recommendations

November 2005

"It may be that, some ages hence . . . the restoration of grey hairs to juvenility and the renewing of the exhausted marrow may at length be elicited without a miracle."

Joseph Glanvill,
Founder Member of the Royal Society,
1661AD

Report & Recommendations

November 2005

Contents: *Page:*

27

ANNEXES

BOXES

Acknowledgements

We are indebted to Mick McLean and Victor Zhitomirsky of Scientific-Generics, part of The Generics Group (Cambridge, UK), for providing us with the global analysis of patenting activity in stem cell research.

We are grateful to Drs Cristina Navarrete, National Blood Service, Julie Daniels, Institute of Ophthalmology, University College London; Harry Navsaria, Institute of Cell and Molecular Science, Queen Mary's School of Medicine and Dentistry; Francois Guillemot & Alex Gould, National Institute of Medical Research, for contributing scientific text to this report.

We thank the Officers of the Science and Innovation Network of the Foreign and Commonwealth Office for supplying us with a comprehensive analysis of international positions in stem cell research.

We are also grateful to Margaret Straughan, Department of Health, for her dedicated and persistent operational support for the Initiative.

Lastly, we acknowledge the enthusiasm and commitment with which researchers, academics and representatives from the commercial sector shared their thoughts and ideas on the future of UK stem cell research.

Executive Summary

Innovation forms the backbone of the knowledge-based economy and stem cell research represents a substantial opportunity for future innovation in the life sciences. The UK currently enjoys a position of strength in this area, largely because of a supportive regulatory environment. To ensure that the UK remains one of the global leaders in stem cell research, the UK Stem Cell Initiative (UKSCI) was established by the Chancellor, Rt. Hon. Gordon Brown, in his March 2005 Budget [***See Annex 1***]. UKSCI was charged with developing a ten-year vision and costed strategy for UK stem cell research, for implementation between 2006-2015 [***See Annex 2***]. Over the last 6 months, UKSCI has consulted widely with academia and the private sector [***See Annex 3***]. Strengths and weaknesses in UK stem cell research have become apparent and, in this report, we present our recommendations for preserving the former while remedying the latter.

The UKSCI vision is for the UK to consolidate its current position of strength in stem cell research and mature, over the next decade, into one of the global leaders in stem cell therapy and technology. The development of new stem cell therapies to treat conditions such as Parkinson's disease, diabetes and heart disease is one of the most exciting and captivating aspects of stem cell research. This is a vital and worthy aspiration for UK stem cell research and it remains important for the public and research community to be inspired, energised and driven by this long-term goal. Although it is reasonable to anticipate that some new stem cell therapies will be developed within the next decade, we must also accept that it is probable that this area will take several decades of small incremental advances in science and medicine to come to fruition. In this context, it is worth remembering that conventional pharmaceuticals take between 12-15 years of research and development to bring a product to market.

In order to deliver direct benefit to patients and to the UK economy in the short to medium term, UKSCI foresee that at least some of the UK's investment in stem cell research could also be strategically directed to more conventional areas of medicine. Our vision encompasses the UK being in the vanguard of this area by developing novel stem cell therapies, but also by exploiting stem cell research and technology to develop safer and more effective pharmaceuticals, by illuminating the processes leading to cancer and by continuing to deepen our understanding of basic stem cell biology.

UKSCI has identified five major themes for development, to maintain and increase the momentum of UK stem cell research over the next decade:

- **A Public-Private Consortium in the UK for the Advancement of Stem Cell Technology:** The establishment of consortium of pharmaceutical, healthcare and biotechnology companies with the UK Government to develop stem cells as a resource for discovery in medicine.

- **Extension of the Capacity of UK Stem Cell Research**: Fortification of infrastructure needed to develop stem cell therapy via support for Centres of Excellence, the UK Stem Cell Bank and Cell Therapy Production Units.

- **Consolidation of Research Funding for UK Stem Cell Research**: The development of the UK as a centre for translational and clinical stem cell research, with the help of a public-private partnership between the Government and the *UK Stem Cell Foundation*, along with continuing strategic investment in basic stem cell research via the Research Councils and private funding bodies.

- **Judicious Regulatory Measures to Enable UK Stem Cell Research**: The favourable regulatory climate in the UK for stem cell research should be extended to include clinical applications.

- **Enhanced Coordination & Communication of UK Stem Cell Research**: More coordinated activities between Government bodies, research councils and stem cell researchers and increased dialogue with the public over the next decade on stem cell research.

To build upon these themes, UKSCI have made 11 recommendations to act as a strategic guide for public and charity sector investment in UK stem cell research over the next decade [***See Box 1***]. Whilst these recommendations have been designed as a cohesive and comprehensive package of measures, UKSCI believes that the implementation of each one should, by itself, enhance UK stem cell research and, therefore, merits consideration.

32

Box 1
The 11 Recommendations of the UK Stem Cell Initiative

Recommendation 1: The UK Government should establish a public-private partnership to develop predictive toxicology tools from stem cell lines.

Recommendation 2: *The UK Stem Cell Bank* should be consolidated in new permanent facilities adjacent to its current site and its operational and development costs should be secured for the next decade.

Recommendation 3: The Research Councils should monitor the emergence of Centres of Excellence in stem cell research, designate them as such and strengthen them with core funding.

Recommendation 4: Research Councils and private sector funding bodies should support the development of stem cell therapy production units at UK Centres of Excellence in stem cell research.

Recommendation 5: The Government and Research Councils should strengthen the levels of funding for basic stem cell research over the next decade.

Recommendation 6: The Government should provide funding for clinical and translational stem cell research over the next decade at a level matching that raised by the UK Stem Cell Foundation (UKSCF), up to a maximum of £10M per annum, and administer it via a UKSCF/ Medical Research Council collaboration.

Recommendation 7: The Department of Health must ensure that the promised increase in R&D resources is forthcoming and furthermore, that the full NHS costs of stem cell clinical research trials within the NHS are supported with extra funding from each Spending Review over the next decade to match the increase in research grants and activity.

Recommendation 8: The Government should continue to ensure that regulation of stem cell research is risk-based and proportionate and does not stifle the development of the full range of safe and effective new cell therapies for the benefit of patients. In particular, (i) the Department of Health should establish a specialised research ethics committee for stem cell clinical research; (ii) the Government should clarify the regulatory requirements for the use of animals and animal cells in human stem cell research; & (iii) for the *in vitro* use of embryonic stem cell lines, researchers should be registered with, and submit an annual research summary report to, the UK Stem Cell Bank.

Recommendation 9: The *UK Clinical Research Collaboration* should help to (i) coordinate organisations supporting stem cell research, including all of the relevant Research Councils and the UK Stem Cell Foundation and (ii) ensure that the *National Health Service* is optimally engaged in this area.

Recommendation 10: The Government should allocate additional funding to establish *The UK Stem Cell Cooperative*, to maximise the cross-fertilisation between those involved in the sub-disciplines of UK stem cell research.

Recommendation 11: The Research Councils, charitable funding bodies, and Government Departments should develop a sustained and coordinated programme of public dialogue on stem cell research over the next decade.

We have estimated that our total programme of recommendations over the next ten years has a projected cost range of some £41M to £104M per annum [*See Section 5.5*]. We have calculated that pre-existing public and private sector funding bodies' investment to support ongoing research efforts in this area is likely to account for approximately £30M per annum over the next decade [*See Box 11*]. It is vital for the UK to maintain this level of investment in stem cell research and we propose that additional investment is made, ranging from approximately £11M to £74M per annum over the next decade, specifically to supplement funding for the new endeavours recommended in this report.

Although, we recognise that stem cell research is one of many demands on the public purse, our view is that the ultimate health and wealth gains that the UK will enjoy are directly proportional to the proposed additional investment. For example, our strategic approach to support for UK stem cell research is likely to attract further home-grown and overseas researchers and investment from the private sector to the UK. The pharmaceutical and healthcare industries are likely to focus their stem cell research activities in close proximity to the international centres of excellence in stem cell and clinical research, such as those we envisage evolving in the UK over the next decade. In addition, any development of stem cell therapies within NHS structures will considerably strengthen the future capacity of our Health Service to deliver regenerative medicine to the future population of the UK.

We commend the foresight and long-term commitment to stem cell research demonstrated by the UK Government in the establishment of this Initiative. As well as prospective wealth creation within the UK economy, our investment is likely to deliver health benefits to patient populations, both in the UK and globally, long into the future.

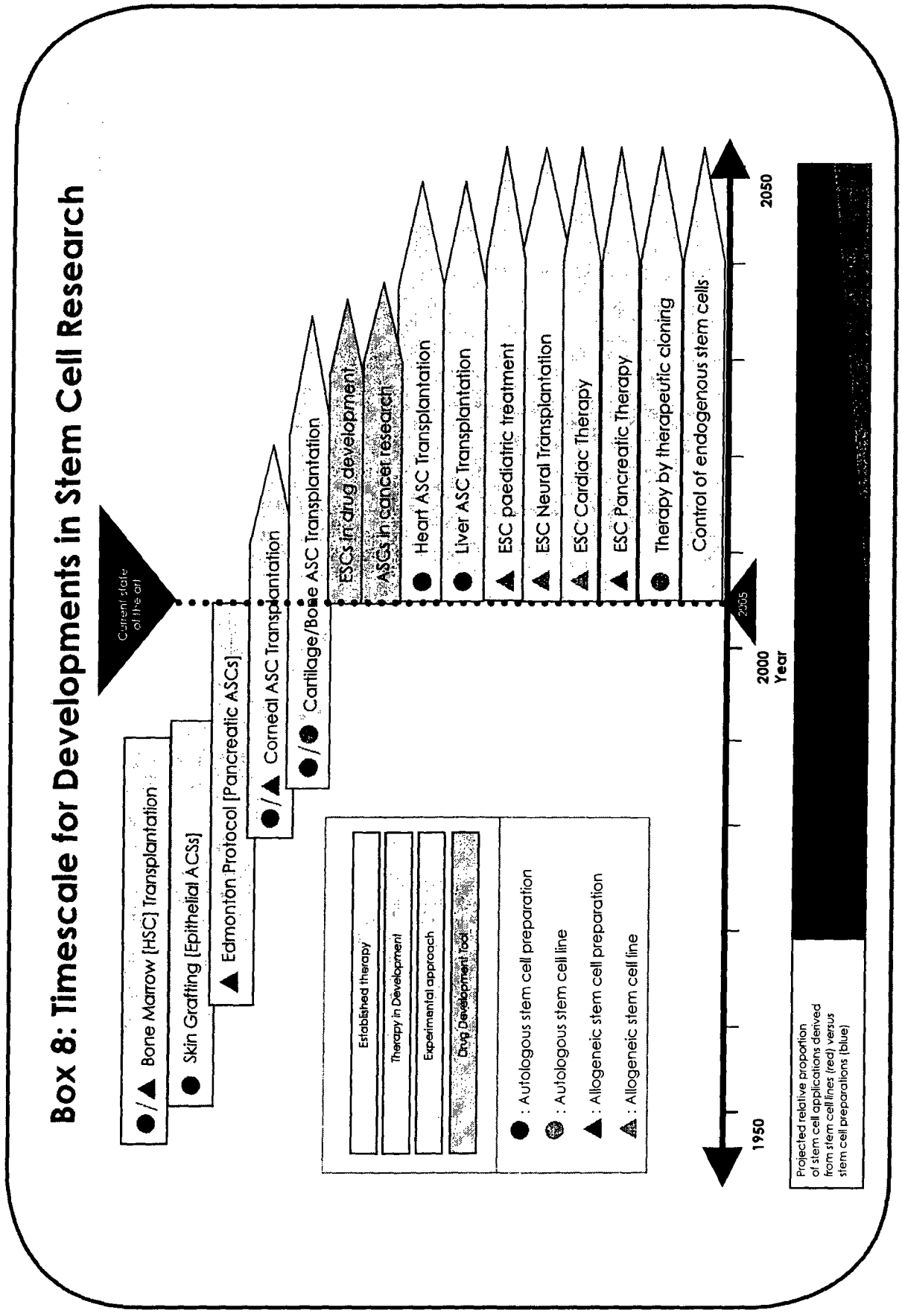
Section 3: Challenges facing Stem Cell Therapy

3.1 Lessons from History

The development of future stem cell therapies is likely to mirror many of the historical aspects of pre-existing stem cell therapies [***See Boxes 4, 6 & 7***]. To that extent, there may be valuable lessons to learn from history. For instance, bone marrow transplantation arose from a desire to convert the basic understanding of immunology, radiation and cancer into clinical benefit for patients. Progress was painstakingly slow, and would not have occurred without experimentation in animals: first in mice, then in dogs. Its success required the parallel development of tissue-matching, materials technology, careful animal experimentation, antibiotics, chemotherapy and the technology of cell separation. Above all, perhaps, the successful development of bone marrow transplantation happened through the dedicated persistence and sustained support for several high-calibre groups of clinical scientists. As with previous stem cell therapies, future stem cell therapies are likely to develop at varying rates and with varying efficiencies [***See Box 8***], reflecting the breadth of problems encountered for each therapy along the way.

3.2 Classification of Stem Cell Therapy

Therapies using *stem cell preparations* that are not manipulated to any significant degree in the laboratory, such as in some types of corneal transplantation, are likely to develop more quickly. But these are also likely to have restricted clinical utility because the cells are not purified, only defined to a limited extent and consequently less controllable.


Box 8: Timescale for Developments in Stem Cell Research
Current state of the art
●/▲ Bone Marrow [HSC] Transplantation
● Skin Grafting [Epithelial ACSs]
▲ Edmonton Protocol [Pancreatic ASCs]
●/▲ Corneal ASC Transplantation
●/● Cartilage/Bone ASC Transplantation
ESCs in drug development
ASCs in cancer research
● Heart ASC Transplantation
● Liver ASC Transplantation
▲ ESC paediatric treatment
▲ ESC Neural Transplantation
▲ ESC Cardiac Therapy
▲ ESC Pancreatic Therapy
● Therapy by therapeutic cloning
Control of endogenous stem cells
2005
1950
2000
Year
2050
Established therapy
Therapy in Development
Experimental approach
Drug Development Tool
●: Autologous stem cell preparation
●: Autologous stem cell line
▲: Allogeneic stem cell preparation
▲: Allogeneic stem cell line
Projected relative proportion of stem cell applications derived from stem cell lines (red) versus stem cell preparations (blue)

36

Legend to Box 8:
Timescales for development of Stem Cell Therapies

Research leading to the first clinical applications of stem cells via bone marrow transplantation began before the 1950's. In the subsequent decades, skin grafting, corneal transplantation, cell therapy for the repair of cartilage and the Edmonton protocol for the treatment of diabetes by transplantation of pancreatic cells from cadavers have been developed to successfully treat patients. All exploit the properties of Adult Stem Cells.

Current stem cell treatments are derived, largely, from *stem cell preparations*. As stem cell research develops over the next decades, an increasing proportion of treatments are expected to take advantage of *stem cell lines*, reflecting an increased level of biological control and purity of stem cell therapies.

The current state of the art for stem cell research seeks to: (i) explore adult stem cells in non-homologous settings, such as the use of HSCs in heart repair; (ii) exploit further sources of stem cells, notably Embryonic Stem Cells, for the treatment of paediatric, heart, pancreatic, liver and brain conditions; (iii) use stem cell lines as tools in drug discovery and development; (iv) increase our understanding and treatment of cancer by further studies of endogenous adult stem cells; & (v) generate embryonic stem cells with the same nuclear genetic material to that of the patient using therapeutic cloning techniques, to avoid the potential rejection of cell therapies. Another ambitious goal for the field involves the use of endogenous stem cells, naturally resident in tissues of the human body, to direct the repair of damaged or diseased tissues. In all of the above examples, timescales are unknown and merely indicative.

Section 4: The Global Landscape

4.1 THE INTERNATIONAL CONTEXT

4.1.1 The International Stem Cell Forum

In 2003, the UK's Medical Research Council convened an International Stem Cell Forum, bringing together nine international research agencies that had already shown an interest in working together to further stem cell research. The objectives of the Forum are to develop collaborative research across nations by encouraging the sharing of resources and data and by identifying schemes that would facilitate trans-national collaborations. Overall, the Forum aims to accelerate progress and improve global practice in stem cell research. The Forum, chaired by Professor Colin Blakemore, Chief Executive of the MRC, now consists of research agencies from sixteen countries.

The Forum has taken forward a number of important issues that were identified as being of particular benefit to the advancement of stem cell research. These include:

1. International Stem Cell Initiative (ISCI): an international expert working group, led by Professor Peter Andrews (Sheffield University), to draw up globally agreed criteria for characterising stem cell lines derived in different laboratories. This information will form the basis of an International Human ES Cell Registry that will be hosted on the Forum Website. The ISCI held its first meeting in August 2005 to review the initial data being generated by the characterisation project. Some 60 delegates, representing all the 17 participating laboratories from around the world, as well as others with key interests, attended. The meeting was successful in bringing together many of the key participants in this newly emerging field to help shape the future of human ES cell research.

The ISCI represents the first attempt to compare and characterise many of the human ES cell lines derived so far. A second initiative is being developed that will build upon the first characterisation study to address several outstanding problems, such as genetic stability and culture conditions, which are fundamental to the future development of stem cell technology.

II. Ethical Landscape Working Group: One of the ISCF's key objectives is to help facilitate international harmonisation of ethical issues relating to use of stem cells in biomedical research. The Canadian Institute of Health Research set up an ethics sub-committee on behalf of the Forum to identify the ethical issues concerning stem cell research that are emerging throughout the world, and how these might best be addressed.

III. IPR Landscape Working Group: On behalf of the Forum the Australian National Health and Medical Research Council has developed a document about intellectual property (IPR) in stem cell science. This IPR 'landscape' document details the broad criteria for patenting stem cells throughout the world, identifying techniques that may be subject to patenting, highlights those patents already in existence, and explains how countries are attempting to ensure ongoing access to stem cell resources. The information provided will be key in encouraging further research and development world-wide.

IV. International Stem Cell Banks: The UK Stem Cell Bank will be leading on identifying best practice for stem cell banking protocols, including derivation, cryogenics and Good Manufacturing Process, and on how Stem Cell Banks worldwide can best interact and co-operate.

4.1.2 International Competition

The global position of stem cell research is becoming increasingly competitive. Research in the US, China, Singapore and South Korea is proceeding apace and with increasing levels of government support. Recent estimates suggest that Australia, China, Israel, Singapore, South Korea and Sweden are each currently investing between £10M and £90M in this area[3]. Perhaps most striking is the situation in the United States. Despite federal restrictions on embryonic stem cell research, the

3 Financial Times/Scientific American Special Report on "The Future of Stem Cells". July 2005

National Institute of Health in the USA spent $517M (£294M) on stem cell research in the fiscal year 2003. Additionally, individual US states are investing substantially in this area. For example, in November 2004, California voted to introduce Proposition 71 into its constitution. This committed $3B (£1.7B) over the next ten years for stem cell research in California.

The regulatory and funding climates in the most competitive countries in stem cell research are summarised below. Further details on global positions in stem cell research are available at: ***www.advisorybodies.doh.gov.uk/uksci/global***

4.1.2.1 AUSTRALIA

The future of stem cell research in Australia is currently being reviewed as the legislation governing the research is due for renewal. The current legislation, which makes therapeutic cloning illegal, has been in force since 2002 and the review must be completed by 19 December 2005. It is expected that the review will call for therapeutic cloning to be allowed.

Research involving stem cells is managed largely by the Australian Stem Cell Centre (ASCC) based at Monash University in Melbourne. The ASCC has links with many universities around Australia and around the world as well as links with corporate partners. Earlier this year, the Bio21 Institute was opened at the University of Melbourne. Bio21 is the Australian research base for Cygenics Ltd who, through their subsidiary Cordlife Pty Ltd, have moved some of their research from the USA to Australia.

Australian stem cell research has a largely therapeutic focus including research into haematopoiesis; cardiac regeneration and respiratory disease. As therapeutic cloning is illegal, the main technology platforms used are embryonic stem cells, obtained from surplus IVF embryos, adult stem cells, tissue repair and immunology. Funding for stem cell research is mainly from the Australian Government and state governments through various funding schemes with some coming from commercial partners.

The UK and Australia have a long history of scientific collaboration and stem cell research is one area that has been successful. However, there

is increasing scope to attract Australian researchers to the UK and to set up international collaborations, both for research and commercial purposes.

4.1.2.2 CANADA

Canada invests C$40M (£18.8M) annually on stem cell research. They have established the Canadian Stem Cell Network to co-ordinate research activity and fund major collaborations with a concentration along product development lines. The country has a long history of stem cell research, with current strengths in diabetes, neural research, cancer/blood, stem cell genomics, cardiac, muscle, stem cell bioengineering and ethics. Parliament passed an Act in March 2004 banning human cloning for reproductive or therapeutic purposes. The Assisted Human Reproduction Act allows Canadian researchers to derive new human stem cell lines from embryos left over after fertility treatment. To date, the generation of two human embryonic stem cell lines has been reported. Canadian research is primarily focused on adult stem cell work with some human embryonic stem cell research now underway.

On a global scale, Canadian spend on stem cell research is probably among the top ten nations but it is used more effectively than elsewhere because of its highly coordinated approach.

4.1.2.3 CHINA

The Chinese government has in recent years earmarked stem cell science for special investment, with the aim that China could take a leading role in a high-profile and potentially very important field at a time when Chinese biotechnologists in general are struggling to compete on innovation with their Western counterparts.

The result is a growing patchwork of well-funded teams in China's major cities researching stem cells from adult, fetal and embryonic sources, some connected to large hospitals. Many of these teams are carrying out work of international standing and publishing in Western journals. A recent mission to China from the UK was impressed with what it saw, judging facilities in the labs it visited to be "superb" and government support "excellent".

Overall, Chinese stem cell researchers are more focused on moving the science into the clinic than on understanding the basic mechanisms of stem cell biology. Scientists and clinicians are eager to pursue clinical trials of cell-based therapies and several such trials are now under way to treat brain injury, corneal disease and neurodegenerative illness. This focus reflects the Chinese government's wider approach to science, which is to concentrate funding on applied sciences rather than "blue skies" research.

The country faces fewer moral or public objections to the use of embryonic stem cells than many Western nations. The production of new human embryonic stem cell lines is legal, as is therapeutic cloning. Public opinion seems – as far as one can tell – to be largely positive and focused on the potential medical benefits.

4.1.2.4 CZECH REPUBLIC

The Czech Republic has a strong position in Stem Cell Research with seven 'stabilized' human embryonic stem cell lines derived at the Laboratory of Molecular Medicine in Brno. Molecular biology including stem cell research is one of the seven long-term research priorities of the Czech Republic. Funding from the Ministry of Health and other funding bodies is project oriented and so far, nobody counts expenditure on stem cells separately, so it is not possible at this time to provide accurate and comprehensive figures. A new government Bill regulating stem cell research passed through the government in July 2005 and will go to the Parliament with expected entry into force in July 2006. The legislation is liberal and in many ways mirrors the UK. The UK is perceived as a partner of choice and Czech researchers have many contacts with leading UK experts in stem cell research.

4.1.2.5 DENMARK

With an amendment to the existing Danish Act on Medically Assisted Procreation, it has been possible for Danish scientists to investigate human embryonic stem cells from national sources from September 1, 2003. Only stem cells derived from up to 14-day-old human embryos that are surplus to treatment by In Vitro Fertilisation. Danish embryonic stem cell research must be approved according to the rules of the scientific ethical committee system.

Since September 1 2003, academics have been expecting a strategy and funds for Danish stem cell research but, to date, this has not materialized. A significant part of Danish stem cell research is undertaken and coordinated by The Danish Centre for Stem Cell Research which was established in April 2002 based on nine existing research groups from universities and private research institutes. Denmark seems to be loosing ground in stem cell research due to lack of funding, but the existing researchers are well recognized globally and have published several findings of international quality.

4.1.2.6 FRANCE

France permitted research on the embryo and embryonic stem cells for the first time in July 2004, although somatic cell nuclear replacement and the creation of embryos for research remain forbidden. Licensing of embryo research will be the responsibility of a new Agence de Biomedecine. The Agency was established in May 2005, but the secondary legislation establishing its full licensing powers is still being prepared. In the interim, a temporary decree published last October establishes an ad hoc committee to consider applications to import, store and carry out research on embryonic stem cells.

French scientists are now trying to catch up, with a few world class groups in developmental biology and the neuroscience applications of stem cells. However, there is still only a small stem cell research community in France and there is no ring-fenced funding or national strategy. In December 2004, a report from the French Academy of Sciences concluded that the stem cell area required additional funding and clarity of strategy.

4.1.2.7 GERMANY

In June 2002, a majority in the German Bundestag (Lower House) agreed the German Stem Cell Act. This bans in principle the import and use of human embryonic stem cells, the production of which is outlawed in Germany. However, the import of human embryonic stem cells and research projects using human embryonic stem cells will be permitted under certain circumstances: (i) alternative forms of research have been exhausted; (ii) only stem cell lines created before 1 January 2002 are used which have come from surplus embryos created for reproduction; (iii) the aims of the research are worthy and of benefit for

society at large; (iv) applications have been assessed by a high-level ethics committee. There is a licensing authority, Robert Koch Institute in Berlin, to administer the system.

The German Research Foundation (DFG), Germany's Research Councils equivalent, produced an overview of its stem cell funding activities in early August 2005. Between 2000-2007, DFG allocations for stem cell research totalled over €70M (£48M). Of this, €60.37M (£41M) was spent on basic stem cell research between 2000-2005 and €10.1M (£7M) was allocated for stem cell clinical research between 2000-2007.

4.1.2.8 INDIA

The Indian government has realised the potential of this new technology in modern therapeutics and biomedical research. It is developing new policy, increasing funding and strongly recommends that stem cell research and its clinical applications be promoted in the country. Over 15 institutions are involved in stem cell research in India. Ethical guidelines are similar to those of the UK and opportunities exist for collaboration and attracting talent to the UK.

4.1.2.9 ISRAEL

Israel has no specific funding or research policy for stem cell research. The largest sum of money dedicated to stem cell research has been through the Ministry of Industry and Trade (MIT) in establishing a Cell Therapy consortium – with funding around $15M (£8.3M). Israel is considered a leader in stem cell research with strengths both in embryonic and adult stem cells. Areas of research include blood, bone, liver, pancreatic, heart and nerve cells. Israel has ten stem cell oriented companies. In March 2004, the Israeli Parliament extended until March 2009 the previous 5-year moratorium on genetic intervention for the purpose of human reproductive cloning. The UK is perceived both as having a sound regulatory system and as a major player in stem cell research.

4.1.2.10 JAPAN

The Japanese Government stance towards stem cell research is firmly in line with that of the UK. Two major factors underpin this. Firstly, Japan is keen to maintain its international scientific competitiveness in life sciences, while a nagging insecurity remains that, for all of its economic

and scientific stature, the country did not make a strong enough contribution to the human genome project. Secondly, the Government has a keen eye to the potential healthcare benefits that such research may bring for Japan's rapidly ageing population.

In line with this positive stance, huge investments have been made in national facilities and fundamental research. However, human embryonic stem cell research and clinical work has remained to a large extent held back by the slow development of the regulatory framework.

4.1.2.11 KOREA

The Korean Government has designated the development of Science & Technology as one of its top policy priorities. In 2004, it allocated US$5B (£2.59B) to support R&D activities - at least US$2B (£1.03B) is directly funded by government ministries, and industrial R&D contributes the rest.

The Ministry of Science and Technology (MOST) has also set up a National Innovation System, which aims to co-ordinate all the institutions, both public and private, that maximise the creation, application and dissemination of knowledge and information from the research base. As part of this innovation systems approach, MOST has identified '10 next-generation growth engines' - these are the ten key growth industries to be prioritised, including next generation biochemical products.

In parallel with these innovation initiatives is an effort to make science and engineering education and research more closely aligned to the needs of industry. Academic scientists and students will receive increases in remuneration and incentives to collaborate, for example by reforming their curriculum to support the S&T industries.

Korea is in a dynamic phase in regard to stem cell research with a supportive government. President Roh said that his government will not ban scientists from conducting research into stem cells and other bioengineering technologies, despite questions over the ethical issues involved. The Presidential adviser on science and technology, Dr Park Ki-young, also stressed the need for the government to guarantee

freedom for stem cell research. The Ministry of Health and Welfare (MOHW) announced on 12 January 2005 that it officially approved the research led by Dr Hwang Woo-suk in 2004 for the first time since the enactment of the 'Act on Bioethics and Safety'. His research is under the control of strict ethical standards set by the government and research institutes.

In July 2005, the government approved a research project by a local genetic engineering laboratory, the Maria Life Engineering Institute. The researchers will be involved in discovery of ways to develop human stem cells that can contribute to curing such illness as Parkinson's disease, spinal cord paralysis and senile dementia. This is the first case approved by the government for such a specific project on the use of human embryonic stem cells.

4.1.2.12 SINGAPORE

Stem Cell research is a major priority for Singapore and is undertaken in a number of government institutes and private companies, generally with significant government stakes. It has rapidly built up expertise in this area, mainly by importing overseas talent, attracted by state-of the-art facilities and significant research funding. Priorities include research on diabetes, heart and blood diseases, cancer and neurodegenerative conditions. Singapore has been responsible for a number of significant breakthroughs. Prof. Ariff Bongso of the National University of Singapore was amongst the first to derive embryonic stem cells from human embryos and also to grow human embryonic stem cells on human feeder rather than animal cells. More recently a Singapore company, CellResearch Corporation, has discovered a new source of stem cells from the outer lining of the umbilical cord.

Expenditure on Stem cell research in Singapore is estimated at around S$40-45m a year (~£13-15m). In July 2005 the British and Singaporean Prime Ministers signed a joint statement on science, engineering and technology which includes an initiative to encourage scientific collaborations and networks.

Stem cell research is identified as a priority area for forging new collaborations between the UK and Singapore. A UK-Singapore stem cell workshop was held in June 2004 at Imperial College and a DTI

GlobalWatch Mission visited Singapore in September 2004. These identified significant opportunities for collaboration with Singapore, in particular using Singapore's state-of-the-art facilities at the Biopolis. Collaborations have already developed or are under discussion resulting from these activities. A second UK-Singapore workshop on stem cell research is planned for 2006. In October 2005 Singapore will host a Keystone Symposium – the first to be held outside North America – on Stem Cells, Senescence and Cancer, dominated by US speakers. In addition to scientific collaboration, potential exists for encouraging Singapore's small but fast-growing biotechnology sector to consider the UK as a research partner and a gateway to Europe. Singapore's ethical and legal environment is similar to that of the UK, where reproductive cloning is banned but research on embryos up to 14 days old is allowed.

4.1.2.13 SWEDEN

Sweden is a world leader in stem cell research, with a regulatory & ethical environment similar to the UK. Increased international competition - and opportunities - are recognised resulting in strong marketing of "Swedish stem cell opportunities" and additional funds for medical (including stem cell) research. Their Research Council "Stem Cell Research Project" amounts to 75m Kr (approx £5.5m) for 2003-2008, but additional funds directed towards individual researchers increase this figure significantly to at least 257.3m Kr (£19m) for 2003-2008. This makes Sweden both a potential collaborator with and competitor for the UK.

4.1.2.14 SWITZERLAND

Switzerland is increasingly active in human embryonic stem cell research, but lack of critical mass in the Swiss research and the commercial spin-out community remains the biggest problem compared with the UK. However, swift passage into law of the pragmatic Swiss Federal Stem Cell Research Act this March and strength in adult stem cell research have opened up a window of opportunity for Switzerland to join international leaders in fundamental research and drug discovery.

There is currently no dedicated Swiss Federal funding programme or mechanism that specifically supports research projects with human

embryonic stem cells. However, since 1990 the Swiss National Science Foundation has funded many individual research projects that investigate adult stem cells. It has also committed budget to such research in other funding programmes.

It is estimated that some £ 2.5 million per annum of Swiss Federal budget is allocated to various projects in adult stem cell research in Switzerland. There is only one research project in Switzerland that works with human embryonic stem cells and this has been receiving a modest annual research budget from the Swiss National Science Foundation.

The Swiss State Secretariat for Education and Research is acutely aware of the opportunity offered by the new legislation now in force and is poised to set up and fund a dedicated new five year National Research Programme on Human Embryonic Stem Cell Research that may be launched as early as 2006. It is estimated that this will receive a new annual budget of about £1M over and above the Federal budget which is in place. Switzerland actively seeks bilateral collaboration with both the UK government and UK research to build the core of this new National Research Programme.

4.1.2.15 UNITED STATES OF AMERICA

The legislative positions of US States regarding stem cell research vary widely, ranging from laws in California, New Jersey, Massachusetts and Connecticut which encourage embryonic stem cell research, including therapeutic cloning, to South Dakota, which strictly forbids research on embryos regardless of the source.

Many states restrict research on aborted fetuses or embryos, but research is often permitted with consent of the patient. Almost half the states also restrict the sale of fetuses or embryos. Louisiana is the only state that specifically prohibits research on IVF embryos. Illinois and Michigan also prohibit research on 'live' embryos. Finally, Arkansas, Iowa, Michigan and North Dakota prohibit research on cloned embryos. Virginia's law also may ban research on cloned embryos, but the statute leaves room for interpretation because 'human being' is not defined and does not specify, whether human being includes blastocysts, embryos or fetuses. California, New Jersey, Massachusetts

and Rhode Island also have human cloning laws, but these laws prohibit cloning only for the purpose of initiating a pregnancy or reproductive cloning, but allow cloning for research. Missouri forbids the use of state funds for reproductive cloning but not for cloning for the purpose of stem cell research, and Nebraska prohibits the use of state funds for embryonic stem cells research.

Although the states are generally behaving in a partisan Republican/ Democrat manner when it comes to stem cell research, there are some controversies, such as in Massachusetts where the Republican governor had fought with and lost to Democratic legislators over the issue.

A number of states have pledged funding for stem cell research. California is leading these efforts and has pledged $3B (£1.7B) during the next decade for stem cell research. Other states such as Wisconsin have committed $375M (£213M), New Jersey $380M (£216M) and Illinois' comptroller has recommended that his state commit $1B (£568M). While states are trying to gather enough resources to recruit lead scientists in the field it remains to be seen if a brain drain to well funded states will occur and to what extent leading researchers and science will follow the money.

4.2 STEM CELL RESEARCH IN THE UK

In March 2005, The UK Stem Cell Initiative was established by the Chancellor, Rt. Hon. Gordon Brown, to produce a vision and strategy to keep the UK at the leading edge of global stem cell research over the next decade.

To achieve this aim, it is important to recognise that UK stem cell research currently has a number of strengths which need to be preserved and a number of weaknesses which need to be remedied. The weaknesses are likely to become increasingly evident as the applied benefits from stem cell research emerge. In order to highlight these elements, we have carried out a SWOT analysis for UK stem cell research [***See Box 9***].

Box 9
SWOT analysis of UK Stem Cell Research

Strengths

- Supportive and consistent Government position
- Enabling regulation for embryonic stem cell research
- Favourable ethical environment & public support
- World-class academic researchers in developmental and reproductive biology
- Strong climate of innovation in UK
- UK Stem Cell Bank
- National Blood Service
- Estimated £30M per annum investment in UK stem cell research from public and charity sector funding bodies
- Strong bio-processing initiative
- Strong clinical trials base and UKCRC

Weaknesses

- Gaps in UK funding for translational research
- Unknown business model & return on investment
- Lack of involvement by big pharmaceutical companies
- Lack of venture capital investment
- Lack of regulatory clarity for clinical use of stem cell therapies
- Lack of central co-ordinated strategy leading to "cottage industry" approach
- Smaller science base than US
- History of innovations being lost to the US for commercialisation phase
- Lack of clarity on Intellectual Property and Licensing Issues

Opportunities

- World leadership in embryonic stem cell therapies
- Enhanced drug development & cancer research
- Use NHS to drive clinical translation
- Redirect UK researchers from developmental biology to stem cell research
- Public investment matched by private funding
- Attract foreign skills as international hub
- Drive international agenda
- Attract international inward investment
- Develop international alliances

Threats

- Lack of infrastructure impedes clinical translation
- 'Brain-drain' to US & Far East
- Intellectual Property captured in US & Far East
- UK biotechnology sector weakens
- EU moves to limit stem cell research
- Clinical trial adverse events unravels public support
- NHS has to import expensive stem cell treatments for care of aging population

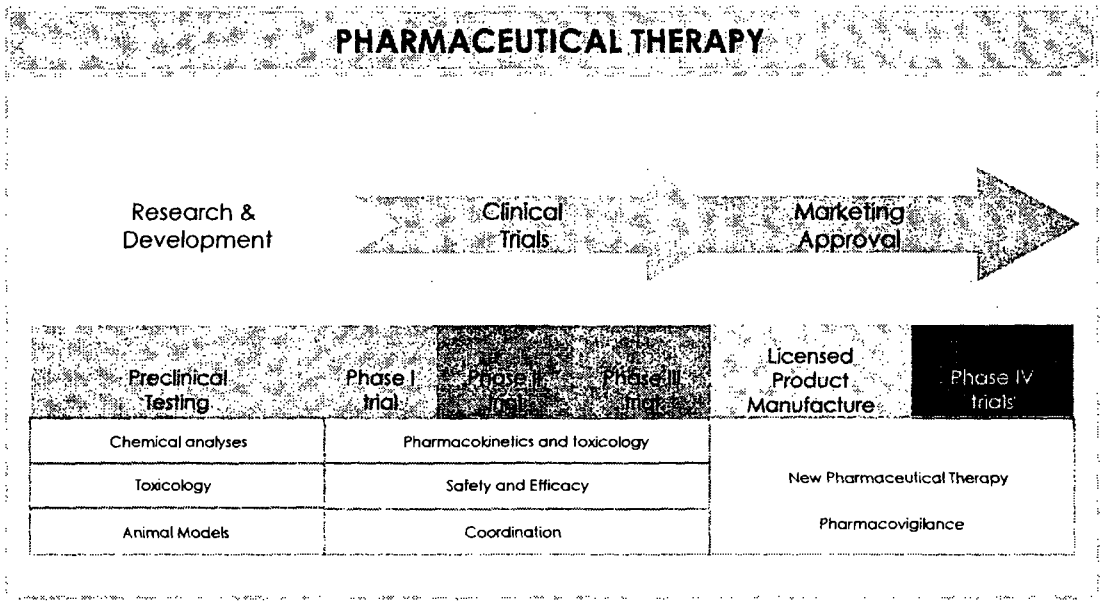
Section 5: Investment Strategy

5.1 RESEARCH CAPACITY

The requirements for the development of stem cell therapies for regenerative medicine are very different from those of more traditional pharmaceutical medicines. This is because any stem cell therapy contains living material and needs to be manufactured, processed and stored in entirely different ways to pharmaceuticals. In the pharmaceutical industry, medicines have been successfully developed over a number of decades through a well-established 'pipeline', which allows the safety and efficacy of drugs to be evaluated at each stage of development [***See Box 14***]. Because this is a tried and trusted approach to drug discovery, the research infrastructure needed to support this pipeline is either already in existence or is readily supported by investment from industry.

Because stem cell therapy is a less developed aspect of medicine than pharmaceutical discovery, there is no established pipeline for the development of stem cell therapies. However, each of the steps required in the development of novel stem cell therapies can be predicted. UKSCI foresees the development of a range of stem cell therapies in the UK via the pipelines of ***Box 15***.

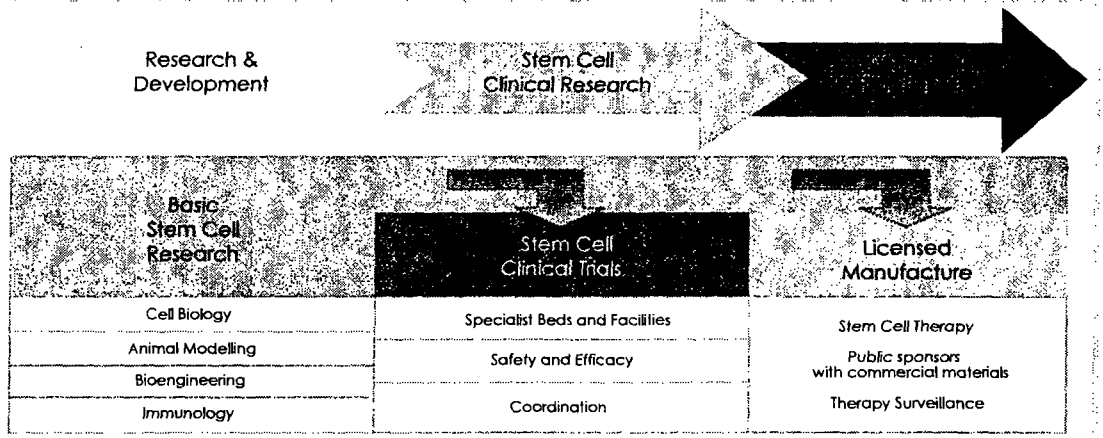
Box 14
The Drug Development Pipeline



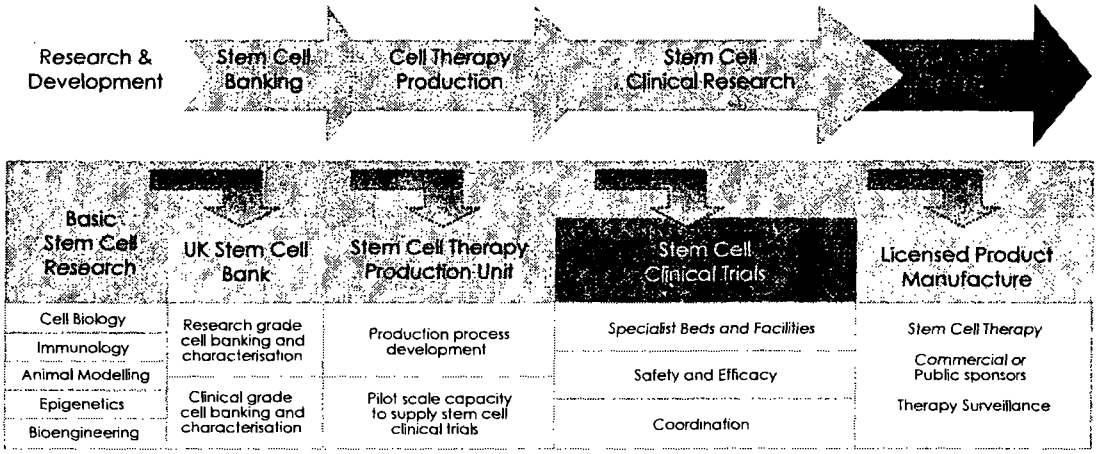
Compounds are tested in the laboratory during the research and development stages. Successful lead candidate drugs are next tested on patients in clinical trials. In Phase I trials, the safety and pharmacological activity of compounds is examined in a small number of people. If proven safe and tolerable, drugs are tested on a greater number of patients in Phase II trials. If the drug shows both efficacy and continued safety, it then passes to Phase III trials, involving a large number of patients. The results from the Phase III trials are used to determine whether the drug can receive a licence from the regulatory agency, which would allow it to be marketed and prescribed by doctors. Marketed drugs continue to be monitored for safety in both the general patient population and in specific 'post-marketing' studies, known as Phase IV trials.

Box 15
Stem Cell Therapy Development Pipelines

(I) THERAPIES PRODUCED FROM STEM CELL PREPARATIONS



(II) THERAPIES PRODUCED FROM STEM CELL LINES



See legend on next page

Legend to Box 15:
Stem Cell Therapy Development Pipelines

Stem cell therapies can be produced from two sources: stem cell preparations, Box 15(I), or stem cell lines, Box 15(II).

Stem cell preparations are isolated from a donor or the patient themselves, as in bone marrow transplantation. Stem cells may sometimes be purified from the preparation before being transplanted into the patient. By contrast, stem cell lines are generated from stem cells that have been derived from donors but grown to homogeneity in laboratory culture. Lines are banked as pure frozen stocks. They can later be expanded to large numbers in the laboratory, differentiated into the therapeutic cell type and transplanted into patients.

During the Research & Development stages, innovations from Basic stem cell research (pink) play a vital role in identifying potentially relevant clinical targets. This area impacts upon all stages of the development of stem cell therapies (indicated by purple arrows). All stem cell therapy requires an understanding of cell biology, bioprocessing and studies in animal models. Allogeneic therapies, as either stem cell preparations or stem cell lines, require knowledge of immune system responses to the transplanted cells.

Stem Cell Banking stages are required to maintain the security and quality of supply of stem cell lines. The UK Stem Cell Bank ensures that cell lines have suitable ethical provenance, are screened for relevant infectious agents and characterised to an appropriate degree. Cell lines can be produced to sufficient quality for clinical or laboratory research applications. At Cell Therapy Production stages, Stem Cell Therapy Production Units develop processes to grow stem cells to a volume which can supply the demand for the large numbers of cells to treat patients in clinical trials.

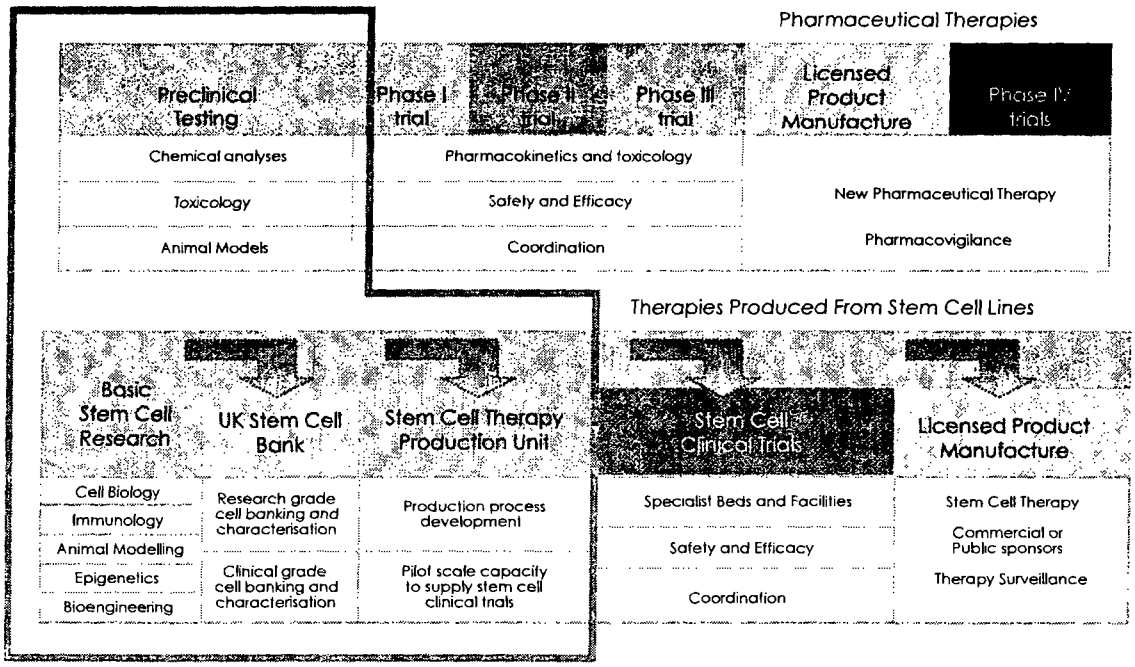
At Stem Cell Clinical Research stages, the safety and efficacy of stem cell therapies derived from both stem cell lines and stem cell preparations are assessed in Stem Cell Clinical Trials. Trials require specialist beds and facilities to monitor the response of patients to treatment. Clinical research requires a considerable degree of coordination, both in managing individual trials and in strategic analyses of funding areas for grant-awarding agencies and policy-makers.

Stem cell preparations tend to have little commercial value and develop as treatments from publicly-sponsored research. As their use reaches Clinical Practice, devices that facilitate the use of these therapies are manufactured under license from the commercial sector. By contrast, therapies developed from stem cell lines have commercial value in themselves and are manufactured as products under license, once they have received Marketing Approval from regulatory agencies. New stem cell therapies are kept under surveillance after marketing approval, to detect any adverse reactions that were not observed during clinical research stages.

Another potential area of specialisation for the consortium could be the development of placental or umbilical cord stem cell banking services and therapies. However, within the time constraints of this report, we have been unable to examine the case for this in sufficient detail.

Perhaps most importantly a public-private consortium focusing on the understanding required for the use of stem cells in predictive toxicology would help develop technology to improve the safety and range of conventional pharmaceuticals and expedite the development of stem cell therapies for regenerative medicine.This would contribute to stem cells having a positive impact on patient's health sooner rather than later.

Recommendation 1: The UK Government should establish a public-private partnership to develop predictive toxicology tools from stem cell lines.



Projected Cost Range of UKSCI Recommendation 1: £16.4 – 31.3M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Management costs[1]	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Costs of research[2]	0.5	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Cost per year	0.7	1.3	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Management costs[3]	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Costs of research[2]	0.5	1	2	3	3	3	3	3	3	3
Cost per year	1.0	1.7	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7

[1]Based on recruitment of a Chief Executive to develop commercial partners, business planning, research portfolio development planning and scientific advisory board, along with additional funding for administrative assistance and office space. Further funding for management team to come from commercial partners.

[2]Figures represent seed Government funding to commission research. Further substantial investment to fund research to be contributed from commercial partners. Costings profiled for each research project to span three years.

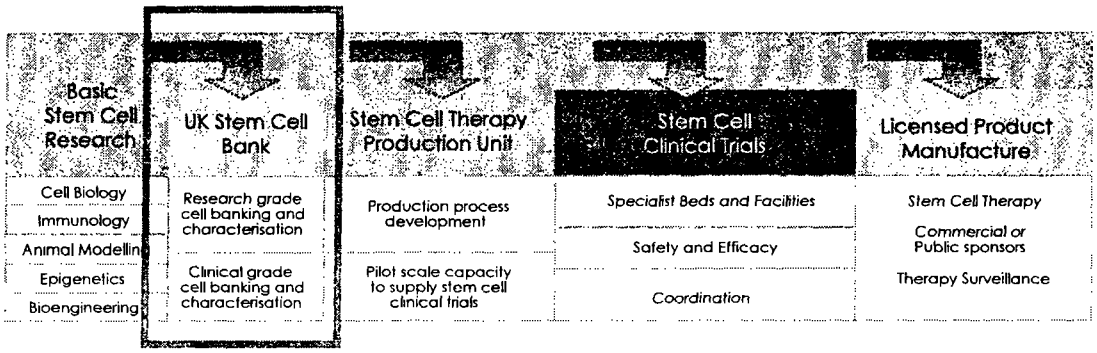
[3]Includes salaries for Chief Executive, Finance Officer, Legal Officer, administrative assistance and office space.

57

5.1.2 Stem Cell Banking

The UK Stem Cell Bank is co-funded by the BBSRC and MRC. It plays a crucial role in ensuring the ethical provenance, quality and secure supply of stem cell lines in the UK. The Bank also contributes to the development of stem cell technology in general and to a stem cell therapy development programme by providing centrally-based expertise in the handling and storage of stem cell lines. The Stem Cell Bank is currently synonymous with embryonic stem cell lines. In the future, it should ensure that it develops expertise in the handling and storage of stem cell lines from all sources, including adult stem cells. The Bank should also ensure that it can accommodate the anticipated increase in requests for withdrawals of stem cell lines over the next decade. In addition to this anticipated increase in transactions, the Bank should become the international centre in the development of stem cell banking protocols, processes and techniques, such as in cryogenics, infection control and Good Manufacturing Practice (GMP).

Recommendation 2: *The UK Stem Cell Bank* should be consolidated in new permanent facilities adjacent to its current site and its operational and development costs should be secured for the next decade.



58

Projected Cost Range of UKSCI Recommendation 2: £17.0 – 20.8M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capital building costs[1]	3.4	0	0	0	0	0	0	0	0	0
Operational costs[2]	1	1	1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
Development costs[3]	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Cost per year	4.6	1.2	1.2	1.3	1.3	1.4	1.5	1.5	1.5	1.5

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capital building costs[1]	4.5	0	0	0	0	0	0	0	0	0
Operational costs[2]	1	1	1	1.2	1.2	1.2	1.3	1.3	1.3	1.3
Development costs[3]	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5
Cost per year	5.9	1.4	1.4	1.6	1.6	1.7	1.8	1.8	1.8	1.8

[1]Single cost expenditure in 2006 to finance permanent facilities for UK Stem Cell Bank.

[2]Maintenance and supply of stem cell lines, salary support, and administration costs, profiled to increase with demand by 2009.

[3]Costs for the development of techniques and protocols in cryogenics, infection control and GMP, profiles to increase in cost by 2011.

5.1.3 Centres of Excellence

The discussions we had as part of this review impressed upon us the multidisciplinary nature of stem cell research, the long-term nature of the endeavour and the relatively small cadre of scientific, clinical and technical staff involved in the UK. Moreover, there is in stem cell research a requirement for somewhat repetitive development and maintenance work for which it is difficult to obtain grants when proposals are in competition with those incorporating novel, hypothesis driven science. Accordingly, high quality, internationally competitive research in the UK will develop in locations that make a, strategic, long-term committment to such research and fund it with contributions from all possible sources. We believe Centres of Excellence in UK stem cell research will evolve in the coming years and play vital roles as:

- locations within the UK where the best researchers can interact and share their ideas, talents and energy;
- dedicated and specialised facilities for multiple aspects of stem cell research;
- hothouses for the specialised training needed to expand the cadre of UK stem cell researchers; and
- infrastructure to attract internationally acclaimed stem cell research groups to the UK.

Central to the rationale for Centres of Excellence is the recognition that there is a considerable danger that a shortage of human resources at all levels will limit the overall capacity for growth of UK stem cell research over the next decade. In particular, it will be critical to ensure that sufficient training opportunities exist for post-graduate and post-doctoral researchers so that they can be attracted to long-term careers in this area. Centres of Excellence should provide such opportunities. In addition, we note that there is a large body of internationally-acclaimed researchers working on developmental and reproductive biology in the UK. In order to increase the number of stem cell researchers in the UK it should be possible to entice some of these into stem cell research. Again, Centres of Excellence should provide the locations and facilities capable of achieving this.

Finally, in terms of existing UK stem cell researchers, it is vital that every effort is made to avoid the loss of these key personnel. One of the principle threats to UK stem cell research comes from international competition. With very substantial levels of funding in California, Singapore, China and South Korea, there are concerns that UK researchers, particularly younger ones, will be attracted to working in these overseas economies. The resultant loss of skilled personnel and intellectual property rights could adversely affect the entire UK biotechnology sector. Encouragingly, the UK is already perceived by both researchers in the UK and abroad as providing a first class regulatory envinment for stem cell research. However, we are aware of one recent instance of a key scientist moving abroad in respose to substantial funding being made available elsewhere. Providing core funding for Centres of Excellence should help combat this.

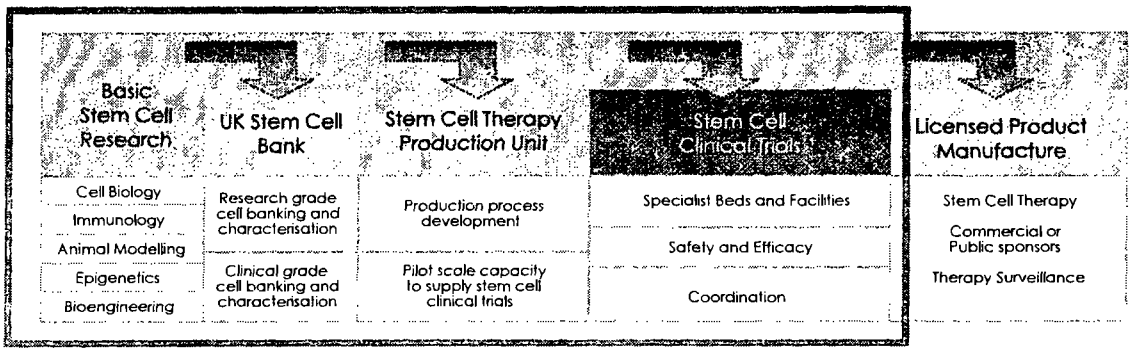
In March 2005, the Academic Subcommittee of the Modernising Medical Careers and UK Clinical Research Collaboration published a report aimed at improving the academic career prospects for medically-qualified researchers in the UK. The committee, chaired by Dr Mark Walport, Director of the Wellcome Trust, set out a clear training pathway for doctors wishing to pursue academic careers. The report's recommendations were supported by £2.5M committed by the Department of Health to pilot the establishment of an integrated academic training programme as a foundation for the academic clinicians of the future. Drawing on the lessons from the Walport report, there is a critical need for contributions from clinical scientists in the early stages of the development of stem cell therapies within the UK research base. Based on their clinical knowledge of the therapeutic area, medically-qualified researchers are best placed to optimise the design and of development of new treatments for patients. The Department of Health should ensure full implementation of the Walport report and funding bodies should prioritise the recruitment of medically-qualified researchers, to be embedded within basic and translational groups in the UK Centres of Excellence in stem cell research.

During the preparation of this review, we have become aware of the possibility of a number of top international scientists in stem cell research moving to the UK. We commend the efforts of Universities and funding bodies to enable these recruitments to occur. Whilst we

recognise that some funds for recruitment are available, for example, via allocations from the Higher Education Funding Council for England (HEFCE), the MRC's Strategic Appointments Awards or the Wellcome Trust's Principal Research Fellowship Scheme, there is a limit to how far this can be achieved without additional resources. Nevertheless, it is of critical importance to be able to grasp these opportunities during the relatively short time they are available. They provide an addittional means of increasing the numbers of scientists involved in stem cell research in the UK. Such researchers are only likely to be attracted to and thrive in Centres of Excellence.

It will be important for the Research Councils to resource the development of such Centres of Excellence if we are to foster an environment in the UK that is conducive for the development of ideas from "bench to bedside". Centres of Excellence should be monitored jointly by the relevant Research Councils, so that excellence in the necessary biological, engineering, social science and the arts and humanities can be recognised. Key to their success will be the availability of sufficient and adequate NHS support for clinical studies. Therefore, additional resources should be requested in Spending Reviews, as necessary.

Recommendation 3: The Research Councils should monitor the emergence of Centres of Excellence in stem cell research, designate them as such and strengthen them with core funding.



62

Projected Cost Range of UKSCI Recommendation 3: £36 – 70M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Centres Of Excellence[1]	2	2	2	2	4	4	4	4	4	4
Recruitment of internationally-acclaimed research groups[2]	2	2	0	0	0	0	0	0	0	0
Cost per year	4	4	2	2	4	4	4	4	4	4

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Centres Of Excellence[3]	2	2	4	4	6	6	8	8	10	10
Recruitment of internationally-acclaimed research groups[4]	2	2	2	0	0	2	0	0	2	0
Cost per year	4	4	6	4	6	8	8	8	12	10

[1]Based on two rounds of designation of UK Centres of Excellence in stem cell research in 2006 & one in 2010.

[2]Based on the recruitment of two internationally-acclaimed research groups, one in 2006 & one in 2007.

[3]Based on five rounds of designation of UK Centres of Excellence in stem cell research in 2006, 2008, 2010, 2012 & 2014.

[4]Based on the recruitment of five internationally-acclaimed research groups, one each in 2006, 2007, 2008, 2011 & 2014.

5.1.4 Cell Therapy Production Units

Currently, there are a number of infrastructure components from the stem cell therapy development pipeline, which are missing from, or are limited in, the UK. Therapies involving stem cell lines will require facilities to allow researchers to develop processes to produce clinical grade batches of cells for use in clinical trials. Our vision for UK stem cell research is to include the development of therapies for regenerative medicine, so we must ensure that the infrastructure for every component of this envisaged pipeline is in place.

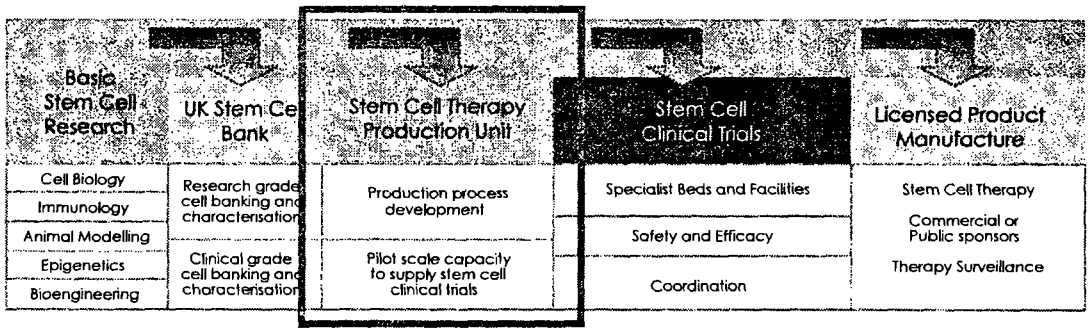
The infrastructure to produce large volumes of cells for clinical trials is essential to the successful development of stem cell research. It will eventually be important to develop multiple national facilities at centres of excellence to maximise the potential for demonstrating proof-of-concept in any particular stem cell therapy.

Such facilities should provide a vital, and currently missing, infrastructural component to a number of research centres and will allow ideas for new treatments to be developed from "bench to bedside." The facilities should be capable of developing processes required to produce clinical grade material derived from both adult and embryonic sources of stem cells and producing pilot-scale clinical grade material for use in clinical trials.

It will be essential to ensure that these facilities are staffed appropriately or their use will be extremely limited. These facilities will act as training centres in the UK for the development of the technical skills base in cell therapy. The availability of long term funding for posts in these facilities will attract technical staff to careers in cell-based therapy.

Until allogeneic stem cell therapy is applied to a range of illnesses in patients, UKSCI believes that the commercial sector is unlikely to fill these infrastructural gaps in the pipeline by investment. It therefore falls to Government, the Research Councils, the National Blood Service and other funding bodies to build this capacity within the UK.

Recommendation 4: Research Councils and funding bodies should support the development of stem cell therapy production units at UK Centres of Excellence in stem cell research.



Projected Cost Range of UKSCI Recommendation 4: £12.2 – 43.4M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capital building costs[1]	2	0	0	0	0	0	0	0	0	0
Operational costs[2]	0	1	1	1	1.2	1.2	1.2	1.2	1.2	1.2
Cost per year	2	1	1	1	1.2	1.2	1.2	1.2	1.2	1.2

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Capital building costs[3]	3	0	3	0	3	0	3	0	3	0
Operational costs[2]	0	1	1	2	2.2	3.2	3.4	4.4	4.6	5.6
Cost per year	3	1	4	2	5.2	3.2	6.4	4.4	8.6	5.6

[1]Based on the development of one Cell Therapy Production Unit in the UK in 2006.

[2]Cell Therapy Production Units' operational costs profiled to increase four years after establishment by 20%.

[3]Based on the development of five Cell Therapy Production Unit in the UK between 2006-2015.

5.2 RESEARCH SUPPORT

UK stem cell research receives considerable financial support from a broad spectrum of funding agencies. In relative terms, current levels of funding for UK stem cell research are competitive internationally, with the exception of the significant federal and state funding in the USA [***See Section 4***]. Over the next decade, the anticipated expansion in the UK stem cell research base will increase the demand for funding in this area in the UK.

5.2.1 Basic stem cell research

Funding bodies believe that the current resources have funded high-quality proposals for stem cell research and that this has been effective in initiating research in this area. We have estimated that the Research Councils are currently spending £15M per annum on this [**See Box 11**]. However, the overall funding of the science base is restricted and stem cell research requires continuing long term investment and is relatively expensive.

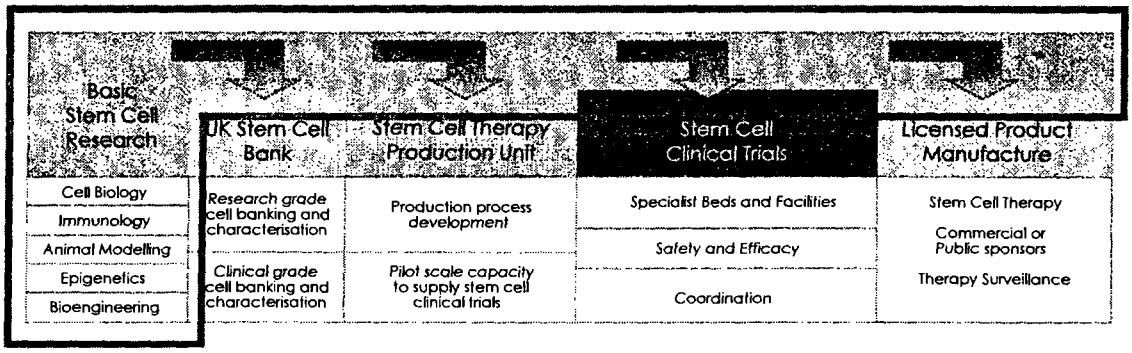
Basic stem cell research will contribute to all stages of stem cell technology and therapy development. It will form the bedrock for any innovation, from which crucial intellectual property rights can be established. High priority should, therefore, be given to integrated research programmes that are interdisciplinary and directed towards the conversion of basic stem cell research into clinical appliciations.

If we are committed to making a contribution to the field in the international context, we must accept the need to fund basic stem cell research to a significant degree. If the UK Stem Cell Bank is to be fully resourced, internationally acclaimed researchers are to be recruited to the UK, Centres of Excellence are to be supported and the benefits of stem cell therapies are to be realised, then more resources for UK stem cell research through conventional channels will be required. Otherwise, other parts of the UK science base will suffer.

While we cannot expect to invest the levels of funding in stem cell research that are being proposed by California, $3B over ten years, the UK Government should be prepared to commit to respond to Spending

Review bids for basic stem cell research. It is impossible to predict how much might be required, but for the purposes of our indicative costings, we estimate that a profiled increase of £5 - 21M per annum will be required over the next decade.

Recommendation 5: The Government and Research Councils should strengthen the levels of funding for basic stem cell research over the next decade.



Projected Cost Range of UKSCI Recommendation 5: £200 – 272M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Existing commitment to Basic Stem Cell Research[1]	15	15	15	15	15	15	15	15	15	15
New Funding for Basic Stem Cell Research[2]	5	5	5	5	5	5	5	5	5	5
Cost per year	20	20	20	20	20	20	20	20	20	20

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Existing commitment to Basic Stem Cell Research[1]	15	15	15	15	15	15	15	15	15	15
New Funding for Basic Stem Cell Research[3]	5	5	7	9	11	13	15	17	19	21
Cost per year	20	20	22	24	26	28	30	32	34	36

[1]Based on the estimated spending by Research Councils on stem cell research in 2005 **[See Box 11]**.

[2]Based on additional spending by Research Councils on stem cell research of £5M per annum between 2006 & 2015.

[3]Based on spending by Research Councils on stem cell research increasing from £5M per annum in 2006 and 2007 and, profiled to increase to £21M per annum by 2015

5.2.2 Translational & Clinical Research

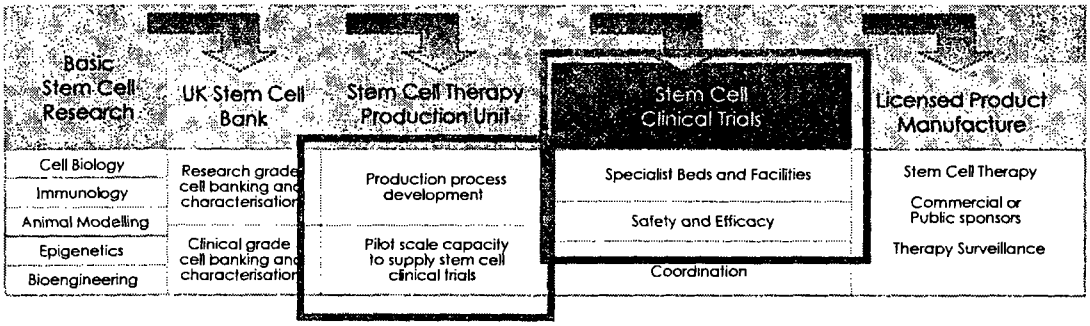
The majority of translational research in the next five years is likely to involve adult stem cells. It is expected that there will be an increasing number of embryonic stem cell applications in the subsequent years. The expertise gained earlier from the development of adult stem cell therapies will expedite the development of therapies involving embryonic stem cells. It is therefore essential that the UK is supportive of early clinical stem cell research trials, provided they are of sufficient quality. This will help to develop our breath of expertise and knowledge of clinical aspects of stem cell research.

The UK Stem Cell Foundation (UKSCF) has been established specifically to fund translational and clinical stem cell research in the UK and seeks to raise substantial funds (up to £10M per annum) from private donations in order to promote this research. The Foundation recognises the emerging potential of stem cell research to create health benefits in the UK and is determined that these opportunities should not be lost. It has suggested that the Government matches the private money raised pound-for-pound.

Consideration should be given to this proposal, as it would effectively halve the cost to the public purse of funding such translational and clinical research in the UK. The research proposed must be of high quality and to ensure this, the UKSCF and the MRC are jointly developing specific selection criteria and a combined review process for the funding of translational stem cell research proposals. If UKSCF/MRC successfully develop this joint process, the Government could administer this new funding via a UKSCF/MRC collaboration. Public money would be allocated to the MRC for the specific purpose of matching UKSCF funding for translational and clinical stem cell research projects.

Should such a partnership prove possible, then it would undoubtedly contribute to the development of stem cell therapy in the UK by providing much needed support for research aimed at clinical application within two years.

Recommendation 6: The Government should provide funding for clinical and translational stem cell research over the next decade at a level matching that raised by the UK Stem Cell Foundation (UKSCF), up to a maximum of £10M per annum, and administer it via a UKSCF/Medical Research Council collaboration.



Projected Cost Range of UKSCI Recommendation 6: £83 – 87M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
UK Stem Cell Foundation[1]	2	5	7	9	10	10	10	10	10	10
Cost per year	2	5	7	9	10	10	10	10	10	10

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
UK Stem Cell Foundation[2]	2	5	10	10	10	10	10	10	10	10
Cost per year	2	5	10	10	10	10	10	10	10	10

[1]Based on a profiled increase in fund-raising by the UKSCF, that requires matching funding of £10M each year by 2010.

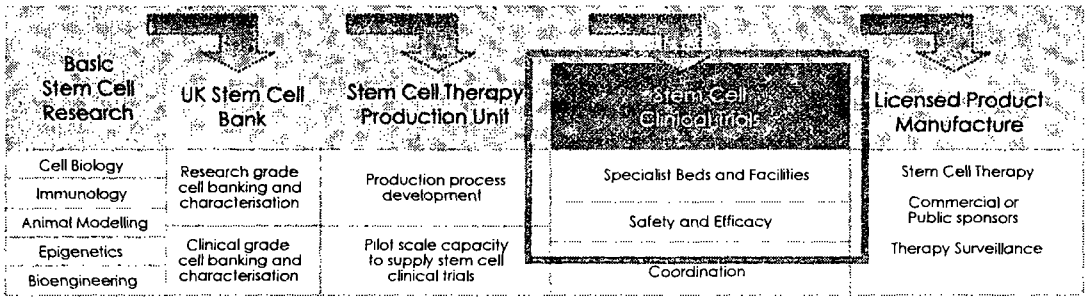
[2]Based on the UKSCF raising funds of £10M (or over) each year from 2006 to 2015.

The new allocation of money to the UKSCF raises a second issue with respect to public funding for translational and clinical stem cell research. These studies are likely to fail if the NHS is unable to support the additional costs of these experimental therapies. Therefore, It will be critical to increase funding of NHS R&D.

As well as the 'Direct Research Costs', the cost of clinical research in the NHS is composed of 'Service Support Costs', which are the extra costs associated with care and monitoring of patients in clinical trials, and the 'Excess Treatment Costs', which are the costs of providing the experimental treatment above those of the standard regimen. Retrospective analyses of clinical research in the NHS reveals that Service Support Costs and Excess Treatment Costs are each equivalent to the Direct Research Costs. That is, the cost of clinical research in the NHS is twice that of the Direct Research Costs.

In 2004, a major increase in the overall NHS R&D allocation was made but, subsequently, much of this increase has been delayed. Should the Government wish to support stem cell clinical research, then the new NHS R&D resource previously promised will have to be restored and additional money to meet the full NHS costs of stem cell trials will need to be made available. We estimate this latter requirement will grow to £32M per annum over the next decade.

Recommendation 7: The Department of Health must ensure that the promised increase in R&D resources is forthcoming and furthermore, that the full NHS costs of stem cell clinical research trials within the NHS are supported with extra funding from each Spending Review over the next decade to match the increase in research grants and activity.



73

[1]Projected Cost Range of UKSCI Recommendation 7: £265.6 – 278.4M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Full NHS Cost[2]	6.4	16	22.4	28.8	32	32	32	32	32	32
Cost per year	6.4	16	22.4	28.8	32	32	32	32	32	32

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Full NHS Cost[3]	6.4	16	32	32	32	32	32	32	32	32
Cost per year	6.4	16	32	32	32	32	32	32	32	32

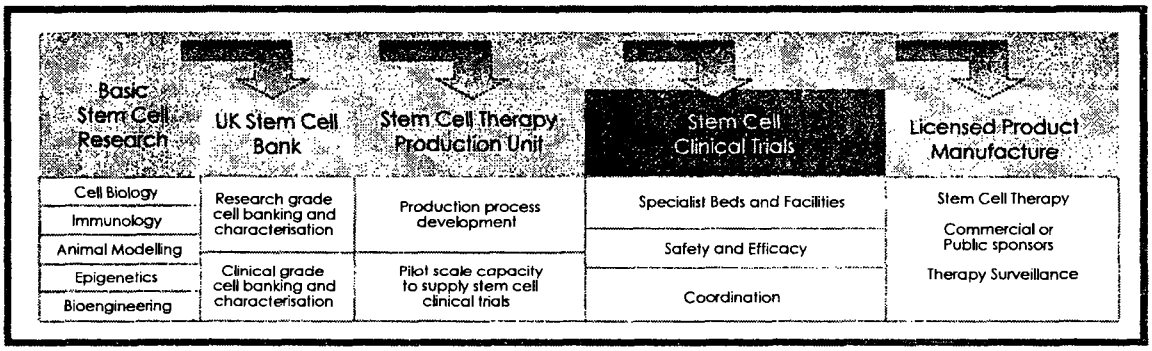
[1]The Full NHS Cost of clinical research is composed of Service Support Costs and Excess Treatment Costs, both of which are the same as Direct Research Costs. Figures are based on funding raised by UKSCF being equivalently matched by public money, as in Recommendation 6. UKSCF estimate that 80% of their funding will support of clinical trials in the NHS. Therefore, the cost per year has been calculated according to the formula: **[Full NHS Cost]= 2 X [0.8 X (Funding raised by UKSCF + Matching public funding to UKSCF)]**.

[2]Based on a profiled increase in fund-raising by the UKSCF that requires matching funding of £10M each year by 2010.

[3]Based on a profiled increase in fund-raising by the UKSCF that requires matching funding of £10M each year by 2008.

74

Recommendation 8: The Government should continue to ensure that regulation of stem cell research is risk-based and proportionate and does not stifle the development of the full range of safe and effective new cell therapies for the benefit of patients. In particular, (i) the Department of Health should establish a specialised research ethics committee for stem cell clinical research; (ii) the Government should clarify the regulatory requirements for the use of animals and animal cells in human stem cell research; & (iii) for the *in vitro* use of embryonic stem cell lines, researchers should be registered with, and submit an annual research summary report to, the UK Stem Cell Bank.



Projected Cost of UKSCI Recommendation 8: £5M

COST (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Stem Cell Therapy Specialised Ethics Committee expenditure[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cost per year	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

[1]Based on figures from similar Government Scientific Advisory Committees in the life sciences.

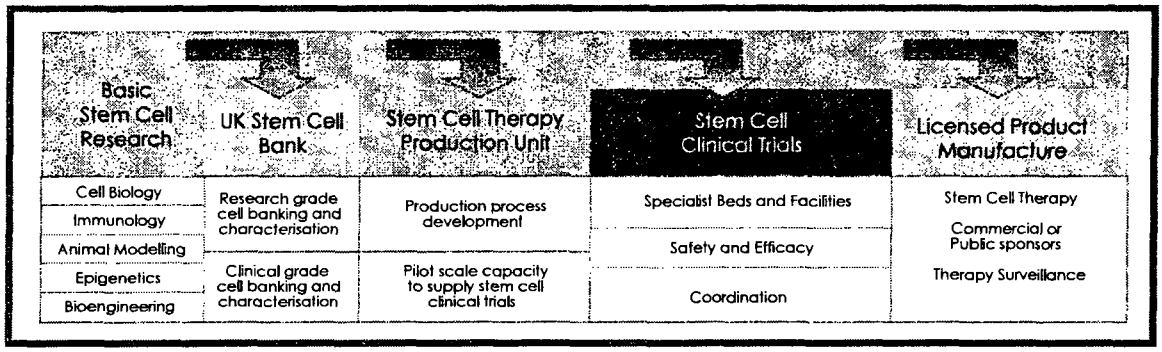
5.4 COORDINATION & COMMUNICATION

5.4.1 Strategic Coordination

As outlined in ***Section 4***, a number of countries offer strengths in stem cell research which are complementary to those of the UK. The Government currently has a number of disparate programmes that promote UK stem cell research and gather information on research globally, such as the DTI *Globalwatch* missions, *UK Trade and Investment* and the *Science and Innovation Network* of the Foreign & Commonwealth Office. Global strategic alliances between the UK and other countries in areas of mutual interest in stem cell research should be developed in a coordinated fashion, based on input from all relevant Government Departments and the Research Councils. The Department of Health, Department of Trade & Industry, Foreign & Commonwealth Office, Research Councils and other relevant Government bodies should coordinate activities to consolidate the global position of UK stem cell research, including via the development of strategic alliances with other countries that have complementary interests to the UK.

Because of the multidisciplinary nature of stem cell research, the Research Councils should continue to work closely together to develop cross-functional research programmes, such as in bioengineering. It continues to be essential for the Research Councils to coordinate their activities if we are to see maximum value for our investment in this area. One of the work streams of the UK Clinical Research Collaboration involves experimental medicine. It would seem a natural progression for the UKCRC to coordinate the efforts of the Research Councils and charitable funding bodies that support stem cell research.

Recommendation 9: The *UK Clinical Research Collaboration* should help to (i) coordinate organisations supporting stem cell research, including all of the relevant Research Councils and the UK Stem Cell Foundation and (ii) ensure that the *National Health Service* is optimally engaged in this area.



Projected Cost of UKSCI Recommendation 9: £1M

COST (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
UKCRC expenditure[1]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cost per year	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

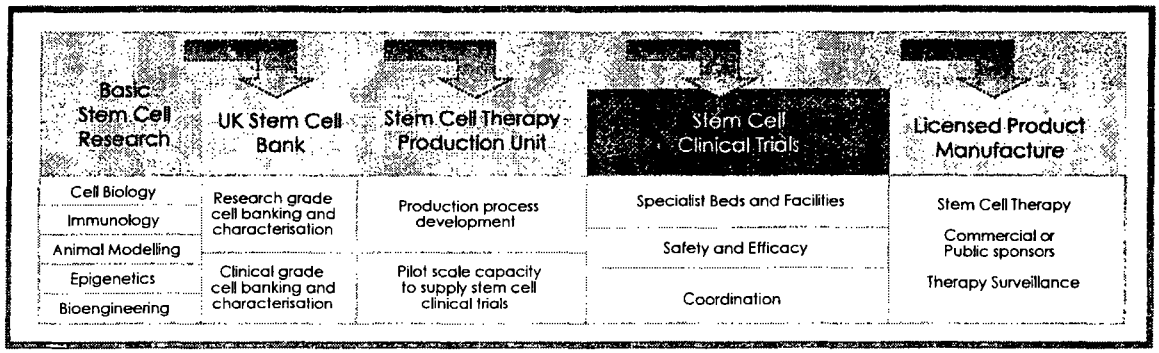
[1]Based on costs of administering of a sub-committee of UKCRC for coordination of stem cell research funders.

5.4.2 The UK Stem Cell Cooperative

One of the crucial elements currently missing from UK stem cell research is a national cooperative, network or forum, for the interaction of scientists, clinicians, ethicists, policy-makers, regulators and commercial organisations with an interest in stem cell research. Stem cell researchers have recognised the need for such associations and established them at regional levels, such as the Scottish Stem Cell Network, the East of England Stem Cell Network and the London Regenerative Medicine Network. A UK-wide cooperative would promote the exchange of ideas and actively facilitate collaboration within both the public and private sectors across the breadth of UK stem cell research.

The UK Stem Cell Cooperative should host regular meetings and establish efficient mechanisms to exchange information and ideas in the area. The Cooperative should also work with the International Stem Cell Forum on the characterisation of stem cell lines, the ethical landscape and intellectual property issues.

Recommendation 10: The Government should allocate additional funding to establish *The UK Stem Cell Cooperative*, to maximise the cross-fertilisation between those involved in the sub-disciplines of UK stem cell research.



Projected Cost Range of UKSCI Recommendation 10: £4.6 – 6M

LOW TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
UK Stem Cell Cooperative[1]	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Cost per year	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5

HIGH TRAJECTORY (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
UK Stem Cell Cooperative[2]	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Cost per year	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

[1]Based on expenditure for annual national scientific conference, regular regional meetings, internet site, administrative costs.

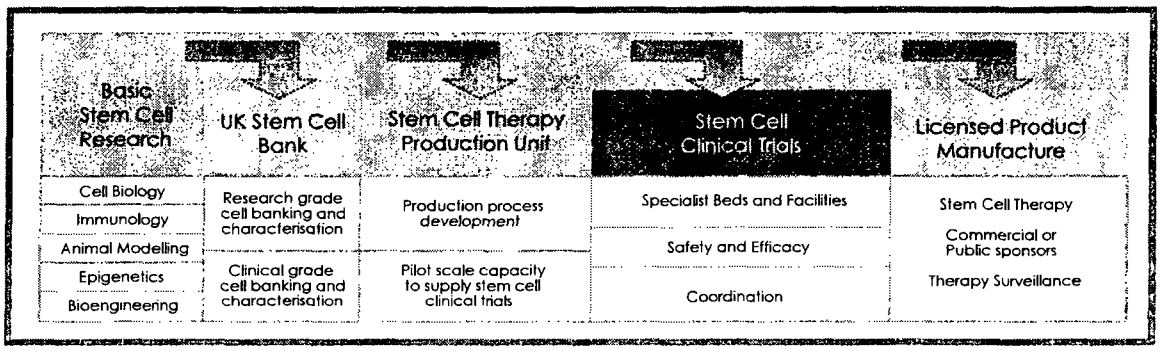
[2]Based on expenditure for annual international scientific conference, regular regional meetings, internet site, administrative costs.

5.4.3 Public Dialogue

The majority of the UK public are currently supportive of stem cell research, as judged in recent opinion polls and via parliamentary debate. However, as research moves towards the clinic it will be important to ensure that the public is kept aware of developments in a balanced and fair manner. As with all clinical research, the safety of treatments is unknown until clinical research takes place. Any adverse events in stem cell clinical research could unravel public support for this technology.

In accordance with the Council for Science & Technology's 2005 report entitled "Policy through dialogue" , it will be critical for the regulation of stem cell research to take due account of public changes in attitude towards this area. Of key importance in the dialogue with the UK public are (i) the ethical issues surrounding the derivation and laboratory use of embryonic stem cell lines (ii) the use of animal experimentation in stem cell research and (iii) the benefits and risks of stem cell therapies.

Recommendation 11: The Research Councils, charitable funding bodies, and Government Departments should develop a sustained and coordinated programme of public dialogue on stem cell research over the next decade.



Projected Cost of UKSCI Recommendation 11: £5M

COST (£M):

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Annual Public Meeting[1]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Educational Programmes[2]	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Cost per year	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

[1]Based on expenditure for one annual meeting on stem cell research for a lay audience.

[2]Based on the development of literature and regional workshops on stem cell research for a lay audience.

5.5 SUMMARISED COSTINGS

In this report, we have made 11 recommendations to act as a strategic guide for public and charity sector investment in UK stem cell research over the next decade. Whilst these recommendations have been designed as a cohesive and comprehensive package of measures, UKSCI believes that the implementation of each one should, by itself, enhance UK stem cell research and, therefore, merits consideration. In the table below, we have summarised the total costs for our programme of recommendations over the next ten years and have projected these to cost in the range of £41M to £104M per annum. We have calculated that pre-existing public and private sector funding bodies' investment to support ongoing research efforts in this area is likely to account for approximately £30M per annum over the next decade [***See Box 11***]. We propose that the UK should maintain this level of investment in ongoing UK stem cell research activity and make an additional investment, ranging from approximately £11M to £74M per annum over the next decade, specifically to supplement the new endeavours proposed in this report. Clearly these cost estimates will need to be updated periodically during the next decade, not least to determine whether the increase in resources required is following a high or low trajectory.

As well as direct funding from Government, Research Councils and private sector funding bodies, UK investment could be augmented from a number of public and private funding sources and enterprises [e.g. ***See Boxes 12 & 16***]. With this level of investment in stem cell research, it is probable that a significant portion of discovery and innovation in the entire field of stem cell research will take place in the UK.

Grand Table for Projected Total Cost Ranges of UKSCI Recommendations

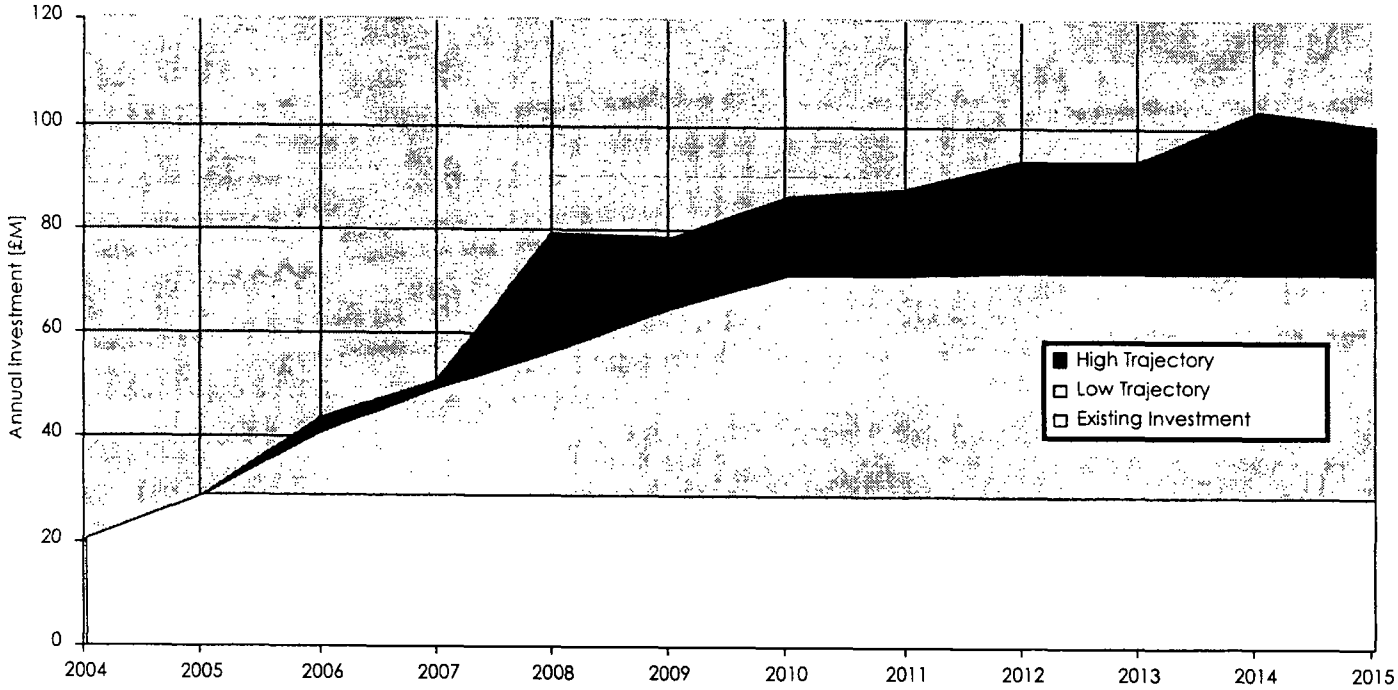
LOW TRAJECTORY (£M):

Recommendation:	Cost over 10 years:	Year									
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 [Public-Private Consortium]	16.4	0.7	1.3	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
2 [UK Stem Cell Bank]	17	4.6	1.2	1.2	1.3	1.3	1.4	1.5	1.5	1.5	1.5
3 [Stem Cell Centres of Excellence]	36	4	4	2	2	4	4	4	4	4	4
4 [Cell Therapy Production Units]	12.2	2	1	1	1	1.2	1.2	1.2	1.2	1.2	1.2
5 [Basic Stem Cell Research]	200	20	20	20	20	20	20	20	20	20	20
6 [UK Stem Cell Foundation]	83	2	5	7	9	10	10	10	10	10	10
7 [Full NHS Costs]	265.6	6.4	16	22.4	28.8	32	32	32	32	32	32
8 [Regulatory Measures]	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
9 [UK CRC]	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
10 [UK Stem Cell Cooperative]	4.6	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
11 [Public Dialogue]	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total cost:	645.8	41.2	50	56.9	65.4	71.9	72	72.1	72.1	72.1	72.1

HIGH TRAJECTORY (£M):

Recommendation:	Cost over 10 years:	Year									
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 [Public-Private Consortium]	31.3	1.0	1.7	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
2 [UK Stem Cell Bank]	20.8	5.9	1.4	1.4	1.6	1.6	1.7	1.8	1.8	1.8	1.8
3 [Stem Cell Centres of Excellence]	70	4	4	6	4	6	8	8	8	12	10
4 [Cell Therapy Production Units]	43.4	3	1	4	2	5.2	3.2	6.4	4.4	8.6	5.6
5 [Basic Stem Cell Research]	272	20	20	22	24	26	28	30	32	34	36
6 [UK Stem Cell Foundation]	87	2	5	10	10	10	10	10	10	10	10
7 [NHS R&D Costs]	278.4	6.4	16	32	32	32	32	32	32	32	32
8 [Regulatory Measures]	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
9 [UK CRC]	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
10 [UK Stem Cell Cooperative]	6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
11 [Public Dialogue]	5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total cost:	819.9	44	50.8	79.8	79	86.2	88.3	93.6	93.6	103.8	100.8

Projected Cost Ranges for UK Stem Cell Research



The graph above plots projected annual investment in UK stem cell research from 2004-2015. 'High Trajectory' and 'Low Trajectory' plots are based on figures from the "Grand Table for Projected Total Cost Ranges of UKSCI Recommendations". Annual investment figures for 2004 & 2005 are based on figures in *Box 11*. 'Existing Investment' plots investment in UK stem cell research based on the maintenance of 2005 levels of spending between 2006-2015.

If you require further copies of this title quote:
271735/*UK Stem Cell Initiative Report & Recommendations* and contact:

DH Publications Orderline
PO Box 777
London SE1 6XH
Tel: 08701 555 455
Fax: 01623 724 524
Email: dh@prolog.uk.com

Textphone: 08700 102 870 (for minicom users)
for the hard of hearing 8am to 6pm Monday to Friday

www.advisorybodies.doh.gov.uk/uksci/
www.advisorybodies.doh.gov.uk/uksci/global/