CULTURE MEDIUM CONTAINING KINASE INHIBITORS, AND USES THEREOF

Introduction

The present invention relates to maintenance of a self renewing phenotype in pluripotent stem cells. The methods and compositions provided are suitable for culturing and isolating pluripotent stem cells such as embryonic stem (ES) cells, especially mammalian, including rat, mouse, bovine, ovine, porcine, and human, stem cells. In particular this invention relates to self-renewing cultures of rat, mouse and human pluripotent cells and to methods and compositions therefor.

Background

The establishment and maintenance of in vitro pluripotent stem cell cultures in the presence of medium containing serum and Leukaemia Inhibitory Factor (LIF) is well known (Smith et al. (1988) Nature 336: 688-90). Such methods have been used to maintain pluripotent embryonic stem (ES) cells from "permissive" strains of mice over many passages. Maintenance and self renewal of pluripotent stem cell cultures is further supported where the stem cells are cultured in the presence of feeder cells or extracts thereof, usually mouse fibroblast cells. Under such conditions it is possible to maintain human ES cells in a pluripotent state over many passages in culture.

In many cases ES cells can only be maintained, or are best maintained, using medium that contains serum or serum extract, and hence is undefined, or using cell culture conditions that require the presence of other cells, such as the fibroblast feeder cells used to maintain human ES cells. But any undefined component, whether in the medium or produced by e.g. the feeder cells, potentially interferes with or hinders research into ES cell propagation and differentiation. This prevents development of good manufacturing practices for therapeutic and other applications of ES cells and their progeny. Some

defined ES cell media are known but alternative and preferably improved defined media are needed.

In prior applications by the applicants, WO-A-03/095628 and a later as yet unpublished application, culturing pluripotent stem cells, such as ES cells, in serum-free media comprising (1) agonists of gp130 (e.g. LIF) and (2) agonists of the TGF-β superfamily (e.g. BMP4) or Id signalling pathways is used to promote self renewal of the stem cells for multiple passages. In the presence of gp130 signalling, an agonist of the TGF-β superfamily or the Id signalling pathway surprisingly provided a self renewal stimulus rather than a pro-differentiation signal. Nevertheless, ever improved efficiencies in maintaining pluripotent cells in a self renewing state and media for transferring pluripotent cells away from feeder cells or away from feeder-conditioned medium is desired.

Sato N, et al, Nat. Med. 2004, Jan 10(1) pp55-63 describe the effects of a Glycogen Synthase Kinase 3 (GSK3) inhibitor, 6-bromoindirubin-3'-oxime, on mouse and human ES cells in serum containing medium. These effects, however, were observed only over a very short time frame, too short for firm conclusions to be drawn, and the influence of unknown factors in the undefined media used in that study may be significant. The inventors of the present invention have tried but failed to repeat the results, and have in fact found effects opposite to those described.

For preparation of ES cell culture media it is desired to provide individual media components in as pure a form as possible. However, most media components are cytokines the purity of which is compromised by the need to manufacture them in cellular systems and then remove potential contaminants from the production broth. Another problem with some cytokines is that they have a narrow range of concentration over which they are effective and non-toxic. Media components which have a broader range and/or are less toxic at higher concentrations would be highly useful. Cytokines can also have limited stability in storage, and more stable media components are sought.

An object of the invention is to overcome or at least ameliorate problems in the art, preferably to provide alternative, more preferably improved, methods of culturing and culture media suitable for pluripotent stem cells, which are capable of supporting self-renewal of said stem cells for many passages. A further object of the invention is to provide an alternative culturing system that permits maintenance of a pluripotent stem cell culture *in vitro* until differentiation of the cells can be induced in a controlled manner. A still further object of the invention is to provide methods and compositions that enhance the derivation and isolation of pluripotent stem cells and facilitate their derivation and isolation from organisms refractory to ES cell isolation or from which pluripotent stem cells have not yet been isolated.

Summary of the Invention

In accordance with the present invention, pluripotent stem cells, such as ES cells, are cultured in medium, preferably serum-free, comprising a MEK inhibitor and a GSK3 inhibitor, or a MEK inhibitor and an antagonist of an FGF receptor. Preferably, the medium comprises a MEK inhibitor, a GSK3 inhibitor and an antagonist of a FGF receptor (e.g. a small molecule GSK3 inhibitor and a small molecule MEK inhibitor and a small molecule FGFR antagonist). Self renewal of the stem cells for multiple passages is thereby promoted. Hence, inhibition of GSK3 and MEK, inhibition of MEK and FGF receptor signaling, or inhibition of GSK3, MEK and FGF receptor signalling in the pluripotent cells provides a self renewal stimulus.

The invention has a number of applications. A combination of GSK3 and MEK, MEK and FGFR or GSK3, MEK and FGFR inhibition can be used to grow pluripotent cells, especially ES cells, and, where they have been derived or grown on feeders, to adapt pluripotent cells, especially ES cells, to grow without feeder cells or a layer of feeder cells, often referred to as feeders or feeder cells. A method of expanding stem cells in culture comprises culturing the cells in the presence of a GSK3 inhibitor and a MEK inhibitor, in the presence of a MEK inhibitor and an antagonist of an FGF receptor, or preferably in the presence of a GSK3 inhibitor, a MEK inhibitor and an antagonist of a FGF receptor. Culture medium can be prepared containing one or more GSK3 inhibitors

and MEK inhibitors, one or more MEK inhibitors and FGFR antagonists and, optionally, one or more MEK inhibitors, GSK3 inhibitors and FGFR antagonists. ES cells can be derived using GSK3 inhibitors and MEK inhibitors, using MEK inhibitors and FGFR antagonists, or using GSK3 inhibitors, MEK inhibitors and FGFR antagonists.

According to a first aspect of the present invention, inhibition of GSK3 and MEK, preferably inhibition of all of GSK3 and MEK and a FGF receptor, in a pluripotent cell is used to promote self-renewal of the cell.

Detailed Description of the Invention

Reference to pluripotent cells includes but is not limited to reference to embryonic stem (ES) cells. Characteristic properties of pluripotent cells, including ES cells, include the expression of multiple genes associated with the pluripotent stage of development, the ability to differentiate into cells representative of any and all tissue types present in the source animal, the ability to contribute to chimeras and, particularly, the ability to contribute to the germ line of chimeras. For example true pluripotent cells, such as ES cells, would be expected to express many, if not all, of the pluripotency-associated genes Nanog, Oct4, FGF4, Sox-2 and alkaline phosphatase. In particular, expression of Nanog, Oct4 and Sox-2 is widely regarded as providing a definitive initial indication that a cell is an ES cell. Germ line transmission in chimeras and the ability to generate teratomas or teratocarcinomas comprising differentiated cells from all three primary germ layers (i.e. endoderm, mesoderm and ectoderm) are also widely regarded as definitive indications of a cell being an ES cell.

Reference to GSK3 inhibition refers to inhibition of one or more GSK3 enzymes. Thus a GSK3 inhibitor can inhibit one member, several members or all members of the family of GSK3 enzymes. The family of GSK3 enzymes is well-known and includes but is not limited to GSK3-α and GSK3-β. A number of variants have been described (see e.g. Schaffer et al.; Gene 2003; 302(1-2): 73-81). In specific embodiments GSK3-β is inhibited. GSK3-α inhibitors are also suitable, and in general inhibitors for use in the

invention inhibit both. A wide range of GSK3 inhibitors are known, by way of example, the inhibitors CHIR 98014, CHIR 99021, AR-AO144-18, TDZD-8, SB216763 and SB415286. Other inhibitors are known and useful in the invention. In addition, the structure of the active site of GSK3-β has been characterised and key residues that interact with specific and non-specific inhibitors have been identified (Bertrand et al.; J Mol Biol. 2003; 333(2): 393-407). This structural characterisation allows additional GSK inhibitors to be readily identified.

The inhibitors of certain embodiments are specific for GSK3-β and GSK3-α, substantially do not inhibit erk2 and substantially do not inhibit cdc2. Preferably the inhibitors have at least 100 fold, more preferably at least 200 fold, very preferably at least 400 fold selectivity for human GSK3 over mouse erk2 and/or human cdc2, measured as ratio of IC_{50} values; here, reference to GSK3 IC_{50} values refers to the mean values for human GSK3-β and GSK3-α. Good results have been obtained with CHIR 99021 and CHIR 98014, which are both specific for GSK3. Examples of GSK3 inhibitors are described in Bennett C, et al, J. Biol. Chem., vol. 277, no. 34, August 23 2002, pp30998-31004 and in Ring DB, et al, Diabetes, vol. 52, March 2003, pp588-595. Suitable concentrations for use of CHIR 99021 are in the range 0.01 to 100, preferably 0.1 to 20, more preferably 0.3 to 10 micromolar.

GSK3 inhibition can also be conveniently achieved using RNA mediated interference (RNAi). Typically, a double-stranded RNA molecule complementary to all or part of a GSK3 gene is introduced into pluripotent cells, thus promoting specific degradation of GSK3-encoding mRNA molecules. This post-transcriptional mechanism results in reduced or abolished expression of the targeted GSK3 gene. Suitable techniques and protocols for achieving GSK3 inhibition using RNAi are known.

Reference to a MEK inhibitor herein refers to MEK inhibitors in general. Thus, reference to a MEK inhibitor refers to any inhibitor a member of the MEK family of protein kinases, including MEK1, MEK2 and MEK3. Reference is also made to MEK1, MEK2 and MEK3 inhibitors. A MEK inhibitor can inhibit one member, several members or all

members of the family of MEK kinases. Examples of suitable MEK inhibitors, already known in the art, include but are not limited to the MEK1 inhibitors PD184352 and PD98059, inhibitors of MEK1 and MEK2 U0126 and SL327, and those discussed in Davies et al (2000) (Davies SP, Reddy H, Caivano M, Cohen P. Specificity and mechanism of action of some commonly used protein kinase inhibitors. Biochem J. 351, 95-105). In particular, PD184352 has been found to have a high degree of specificity and potency when compared to other known MEK inhibitors. Other MEK inhibitors and classes of MEK inhibitors are described in Zhang et al. (2000) Bioorganic & Medicinal Chemistry Letters; 10:2825-2828.

Inhibition of MEK kinases can also be conveniently achieved using RNA-mediated interference (RNAi). Typically, a double-stranded RNA molecule complementary to all or part of a MEK gene is introduced into pluripotent cells, thus promoting specific degradation of MEK-encoding mRNA molecules. This post-transcriptional mechanism results in reduced or abolished expression of the targeted MEK gene. Suitable techniques and protocols for achieving MEK inhibition using RNAi are known.

A number of assays for identifying kinase inhibitors, including GSK3 inhibitors and MEK inhibitors, are known. For example, Davies et al (2000) describe kinase assays in which a kinase is incubated in the presence of a peptide substrate and radiolabelled ATP. Phosphorylation of the substrate by the kinase results in incorporation of the label into the substrate. Aliquots of each reaction are immobilised on phosphocellulose paper and washed in phosphoric acid to remove free ATP. The activity of the substrate following incubation is then measured and provides an indication of kinase activity. The relative kinase activity in the presence and absence of candidate kinase inhibitors can be readily determined using such an assay. Downey et al. (1996) J Biol Chem.; 271(35): 21005-21011 also describes assays for kinase activity which can be used to identify kinase inhibitors.

Reference to an antagonist of fibroblast growth factor (FGF) receptor (FGFR) refers to a polypeptide or small molecule or other antagonist of a FGF receptor, typically inhibiting FGFR1 and/or FGFR2. Thus, a FGF receptor antagonist can be an antagonist of one,

several or all members of the FGF receptor family, including but not limited to FGFR1, FGFR2, FGFR3 and FGFR4. Members of the FGF receptor family typically comprise three immunoglobulin-like domains and present a region of acidic amino acids (the acidic box) which can participate in the binding of a member of the FGF family to a FGF receptor. In some cases, molecules comprising only two immunoglobulin-like domains can also function as FGF receptors. A number of FGFR antagonists are known, including but not limited to SU5402 and PD173074. A number of FGFR antagonists are known, for example SU5402 and PD173074. Suitable concentrations of SU5402 are in the micromolar range, such as from 0.1 - 20 μM, preferably 0.5 - 10 μM, especially in the range 1 – 5 μM. We have found that PD173074 can substitute for SU5402 and is fully effective at about 100-fold lower concentrations, consistent with its higher affinity for the FGF receptor. Thus, suitable concentrations for PD173074 are in the range 1-200 nM, preferably from 5-100 nM, especially in the range 10-50 nM. It is also known to inhibit FGR receptor signalling by transgene expression of a dominant negative mutant FGF receptor. In embodiments of the invention, however, it is preferred to use a small molecule antagonist and not a transgenic based antagonism.

Suitable assays for identifying antagonists of FGF receptors are known. For example, a cell line in which signalling via a FGF receptor activates expression of a reporter gene can be used to assess the activity of a potential antagonist.

It has advantageously been found that the use of a MEK inhibitor in combination with a GSK3 inhibitor and preferably also an antagonist of the FGF receptor improves the propagation of ES cells.

In preferred embodiments between around 0.1 μM and around 25 μM MEK inhibitor are used. Further preferably, between around 0.1 μM and around 5 μM MEK inhibitor are used, more preferably from 0.2 μM to 2 μM.

Particularly preferred media according to the invention comprise 0.8 μM PD184352, 3 μM CHIR99021 and/or 3 μM SU5402. A particularly preferred medium comprises 0.8 μM PD184352, 3 μM CHIR99021 and 3 μM SU5402, preferably in N2B27 medium.

The concentration of SU5402 can be optimized to suit different pluripotent cell lines, typically in the range 1-5 μM (e.g. 2μM).

In examples below, we have cultured mouse ES cells in the presence of a GSK3 inhibitor together with a MEK inhibitor and, in a specific example, an antagonist of the FGF receptor to promote self renewal. In other specific examples, a method of promoting self-renewal of mouse pluripotent cells in culture comprises inhibiting GSK3 and MEK or inhibiting GSK3, MEK and an FGF receptor.

Optionally, activating gp130 downstream signalling can also be employed to further enhance the promotion of self renewal by inhibiting GSK3 and MEK. Molecules that activate gp130 downstream signaling are sometimes referred to as gp130 activators or gp130 agonists. Activation of one or more gp130 downstream signalling pathways can be achieved by use of a cytokine acting through gp130, for example a cytokine or other agonist of the LIF receptor. Cytokines capable of acting through gp130, and thus of activating gp130 signal transduction, include but are not limited to LIF, ciliary neurotrophic factor (CNTF), cardiotrophin, oncostatin M, IL-6 plus sIL-6 receptor, hyper IL-6 and IL-11. Suitable cytokines include mimetics, fusion proteins or chimaeras that can bind to and/or activate signalling though gp130. The role of cytokines acting through gp130 in the presence of serum is well established, but the capacity of those cytokines to sustain undifferentiated cells in the absence of serum is limited.

An advantage of the invention is that in the presence of a GSK3 inhibitor, a MEK inhibitor and, optionally, an antagonist of the FGF receptor, pluripotent cells can be grown in defined medium. A particular advantage associated with using the combination of a GSK3 inhibitor, a MEK inhibitor and an antagonist of the FGF receptor is that it is not necessary for the medium to contain other growth factors, such as insulin, N2B27, or a gp130 agonist (e.g. LIF). The present invention therefore enables alternative and/or improved culture of ES cells in medium that is free of serum, serum extract, feeder cells and feeder cell extract.

Purported embryonic stem cells have been reported from a number of mammalian sources including mouse (Bradley et al (1984) Nature 309: 255-56),, American mink (Mol Reprod Dev (1992) Dec; 33(4):418-31), pig and sheep (J Reprod Fertil Suppl (1991);43:255-60), hamster (Dev Biol (1988) May; 127(1):224-7) and cow (Roux Arch Dev Biol (1992); 201: 134-141). Specific examples herein use mouse and human ES cells and also rat cell from primary outgrowths. It will be appreciated that the methods and compositions of the present invention are suitable for adaptation to culturing of other mammalian pluripotent cell cultures, thus including primate, especially human, rodent, especially mouse and rat, and avian pluripotent stem cells, especially ES cells.

A second aspect of the invention provides a method of culture of pluripotent cells, especially ES cells, so as to promote self renewal, comprising maintaining the cells in medium containing:-

(1) an inhibitor of GSK3; and
(2) an inhibitor of MEK.

Preferably, the method comprises maintaining the cells in medium containing:-

(1) an inhibitor of GSK3;
(2) an inhibitor of MEK; and
(3) an antagonist of an FGF receptor.

Methods of the invention can be used generally for growing pluripotent cells, including growing ES cells in medium which is free of serum and free of serum extract, which cells have previously been passaged in the presence of serum or serum extract. Preferably, such methods are also carried out in the absence of feeder cells and/or feeder cell extracts. For example, culture of ES cells can be carried out comprising the steps of:-

- maintaining the ES cells in a pluripotent state in culture, optionally on feeders;
- passaging the ES cells at least once;

- withdrawing the serum or the serum extract from the medium and withdrawing the feeders (if present), so that the medium is free of feeders, serum and serum extract; and

- subsequently maintaining ES cells in a pluripotent state in the presence of an inhibitor of GSK3, a MEK inhibitor and, optionally, an FGFR antagonist.

Further optionally, the cells can be maintained in a pluripotent state in the presence of a MEK inhibitor, a GSK3 inhibitor and an activator of a gp130 downstream signalling pathway.

The present invention also provides a method of obtaining a transfected population of ES cells, comprising:-

- transfecting ES cells with a construct encoding a selectable marker;
- plating the ES cells;
- culturing the ES cells in the presence of a MEK inhibitor, a GSK3 inhibitor and, optionally, an FGFR antagonist;

and

- selecting for cells that express the selectable marker.

Further optionally, the cells are cultured in the presence of a MEK inhibitor, a GSK3 inhibitor and an activator of a gp130 downstream signalling pathway.

The selectable marker may encode antibiotic resistance, a cell surface marker or another selectable marker as described e.g. in EP-A-0695351, and preferably comprises a nucleotide sequence encoding the selectable marker operatively linked to a promoter which preferentially expresses the selectable marker in desired cells.

In a further embodiment, the present invention provides a method of culture of pluripotent, especially ES, cells, comprising the steps of transferring an individual cell to a culture vessel, such as an individual well on a plate, and culturing the cell in the presence of a GSK3 inhibitor, a MEK inhibitor and, optionally, an FGFR antagonist, so as to obtain a clonal population of pluripotent, especially ES, cells, all of which are

progeny of a single cell. Optionally, the cells may also be cultured in the presence of an activator of gp130 downstream signalling pathways.

Once a stable, homogenous culture of ES cells is obtained, the culture conditions can be altered to direct differentiation of the cells into one or more cell types selected from ectodermal, mesodermal or endodermal cell fates. Addition of, or withdrawal of cytokines and signalling factors, can enable the derivation of specific differentiated cell populations at high efficiency. Differentiation of an ES cell towards a non-neuroectodermal fate may be achieved by maintaining the ES cell in the presence of a cytokine acting through gp130, a MEK inhibitor and a GSK3 inhibitor and then withdrawing the cytokine whilst maintaining the GSK3 inhibitor and MEK inhibitor and/or adding a further signalling molecule capable of directing differentiation. Alternatively, the cells may be maintained in the presence of a MEK inhibitor and a GSK3 inhibitor and then differentiation directed by withdrawing one or both of the inhibitors and/or adding a signalling molecule capable of directing differentiation. The methods described above all optionally include the step of obtaining and/or isolating a differentiated cell which is the product of the process.

Further aspects of the invention provide for cell culture media. One medium is for self-renewal of pluripotent, especially ES, cells, the medium comprising an inhibitor of GSK3, an inhibitor of MEK and, optionally, an FGFR antagonist. The medium may also optionally comprise an activator of a gp130 downstream signalling pathway. Another medium of the invention is a stem cell culture medium, comprising an inhibitor of GSK3, a MEK inhibitor and, optionally, an FGFR antagonist. All media preferably further comprise basal medium. In some preferred embodiments, all media are free of an agonist of gp130, hence are preferably free of LIF.

The invention provides medium that is free of serum and serum extract. One such medium comprises:-

- basal medium;
- a MEK inhibitor;
- a GSK3 inhibitor; and

- an iron-transporter;

wherein the medium is optionally free of serum and serum extract.

The medium preferably also comprises an FGFR antagonist. The medium may also optionally comprise an activator of a gp130 downstream signalling pathway.

Preferred medium for pluripotent stem cells, especially rat or mouse cells, may be free of serum and of gp130 agonists and comprises a MEK inhibitor, a GSK3 inhibitor, and an antagonist of an FGF receptor. Substitutions of media components can be made as described herein.

Basal medium is medium that supplies essential sources of carbon and/or vitamins and/or minerals for the cells. The basal medium is generally free of protein and incapable on its own of supporting self-renewal of cells. The iron transporter provides a source of iron or provides the ability to take up iron from the culture medium. Suitable iron transporters include transferrin and apotransferrin. It is preferred that the medium further comprises one or more of insulin or insulin-like growth factor and albumin (preferably recombinant) or albumin substitute, and is free of feeder cells and feeder cell extract. The medium may also comprise an inhibitor of apoptosis or any other component that promotes the maintenance of pluripotent cells in culture.

A particular medium of the invention comprises MEK inhibitor, GSK3 inhibitor, insulin, albumin and transferrin, with or without additional basal medium. In this medium, LIF can be optionally included and can be substituted by other activators of gp130 signalling, though preferred medium comprises the gp130 receptor binding cytokine, LIF, suitable concentrations of which are generally between 10U/ml and 1000U/ml, more preferably between 50U/ml and 500U/ml, even more preferably in the region of 100 U/ml. The GSK3 and MEK inhibitors are preferably as described herein in more detail.

The invention further provides a method of deriving a pluripotent cell from a blastocyst, comprising:-

(1) obtaining a blastocyst;

(2) culturing the blastocyst in the presence of a MEK inhibitor, a GSK3 inhibitor and, optionally, an antagonist of an FGF receptor, to obtain an inner cell mass;

(3) dissociating the inner cell mass;

(4) isolating a cell or cells from the dissociated inner cell mass; and

(5) culturing the isolated cell or cells in the presence of a MEK inhibitor, a GSK3 inhibitor and, optionally, an antagonist of an FGF receptor.

Optionally, the isolated cell or cells are cultured in the presence of a MEK inhibitor, a GSK3 inhibitor and an activator of gp130 downstream signalling. An antagonist of an FGF receptor may also be present.

Preferably, the method comprises culturing the blastocyst in LIF, more preferably for a period of from 2 to 4 days. The isolated cell or cells are preferably cultured in serum free medium. Typically, the cells are replated as clumps. The blastocyst is also preferably cultured in serum free medium, optionally in the absence of an agonist of the BMP receptor.

It is further preferred, according to the invention, that culture of cells is carried out in an adherent culture, which may be promoted by the inclusion of a cell adhesion protein on culture substrate. It is also preferred to culture pluripotent cells according to the invention in monolayer culture, though it is optional for cells to be grown in suspension culture or as pre-cell aggregates; cells can also be grown on beads or on other suitable scaffolds such as membranes or other 3-dimensional structures.

Culture medium used in the examples of the invention preferably also comprises serum albumin. This can be used in purified or preferably recombinant form, and if in a recombinant form this has the advantage of absence of potential contaminating factors,

cytokines etc. The culture medium does not need to contain serum albumin and this component can be omitted or replaced by another bulk protein or by a synthetic polymer (polyvinyl alcohol) as described by Wiles et al.

A particularly preferred medium of the invention is one that is fully defined. This medium does not contain any components which are undefined, that is to say components whose content is unknown or which may contain undefined or varying factors that are unspecified. An advantage of using a fully defined medium is that efficient and consistent protocols for culture and subsequent manipulation of pluripotent cells can be derived. Further, it is found that maintenance of cells in a pluripotent state is achievable with higher efficiency and greater predictability and that when differentiation is induced in cells cultured using a defined medium the response to the differentiation signal is more homogenous than when undefined medium is used.

The invention also provides concentrates which can be used as additives for culture medium, and kits of components, for preparation of culture medium, the resultant medium being in accordance with the invention. One kit of the invention comprises first and second containers, the first containing a MEK inhibitor and the second containing a GSK3 inhibitor. Preferably, the kit comprises a third container containing an antagonist of a FGF receptor. The kit may also, optionally, comprise a further container containing an activator of gp130 downstream signalling. The kits are preferably formulated so that the contents of each container can be added to culture medium so as to obtain a culture medium of the invention. The kits preferably contain concentrated stock solutions of their respective components.

Methods of the invention also include a method of obtaining a differentiated cell comprising culturing a pluripotent cell as described and allowing or causing the cell to differentiate, wherein the cell contains a selectable marker which is capable of differential expression in the desired differentiated cell compared with other cell-types, including pluripotent stem cells, whereby differential expression of the selectable marker results in preferential isolation and/or survival and/or division of the desired differentiated cells. The selectable marker may be expressed in the desired differentiated

cells but not expressed in other cell types, or the level of expression may differ between desired differentiated cells and other cell types, thereby allowing selection for expression of the selectable marker. The differentiated cell can be a tissue stem or progenitor cell, and may be a terminally differentiated cell.

Generally also, the invention extends to a cell obtained by following any of the methods of the invention described herein. Cells of the invention can be used in assays for drug discovery. Cells of the invention may also be used for cell therapy, and thus a method of the invention comprises using a combination of inhibition of MEK and inhibition of GSK3 and, optionally, antagonism of FGF signalling to derive and/or maintain pluripotent cells, deriving cells for cell therapy therefrom and using those cells in cell therapy. Optionally, the combination is used in the absence of an activator of gp130 downstream signalling.

Further aspects of the invention relate to the use of inhibition of MEK and an FGF receptor, optionally in combination with inhibition of GSK3 for promoting self-renewal of pluripotent cells. We have found that the combination of a MEK inhibitor and an antagonist of an FGF receptor is effective in supporting the growth of pluripotent cells in serum-free medium in the absence of added cytokines or growth factors.

Accordingly, a further aspect of the invention provides a culture medium, comprising a MEK inhibitor and an antagonist of an FGF receptor. The MEK inhibitor and the antagonist of an FGF receptor are as described in relation to other aspects of the invention. Similarly, the culture medium may further comprise additional components or factors as described herein in relation to other aspects of the invention.

Yet another aspect of the invention provides use of a MEK inhibitor and an antagonist of an FGF receptor in manufacture of a culture medium for pluripotent cells.

The invention also provides methods for culturing pluripotent cells and obtaining transfected populations of pluripotent cells, which may be conveniently carried out as described for other aspects of the invention. Accordingly, a further aspect of the

invention provides a method of culture of pluripotent cells so as to promote self renewal, comprising maintaining the cells in medium comprising a MEK inhibitor and an antagonist of an FGF receptor.

A related aspect of the invention provides a method of culture of pluripotent cells, comprising the steps of:-

- maintaining the ES cells in a pluripotent state in culture, optionally on feeders,
- passaging the ES cells at least once;
- withdrawing serum or serum extract (if present) from the medium and withdrawing the feeders (if present), so that the medium is free of feeders, serum and serum extract; and
- subsequently maintaining ES cells in a pluripotent state in the presence of a MEK inhibitor and an inhibitor of an FGF receptor.

A further aspect of the invention provides a method of obtaining a transfected population of ES cells, comprising:-

- transfecting ES cells with a construct encoding a selectable marker;
- plating the ES cells;
- culturing the ES cells in the presence of a MEK inhibitor and an FGF receptor antagonist and
- selecting for cells that express the selectable marker.

Also provided is a cell culture medium that is free of serum and serum extract and comprises:-

- basal medium;
- a MEK inhibitor;
- an antagonist of an FGF receptor; and
- an iron-transporter.

The combination of a MEK inhibitor and an antagonist of an FGF receptor is also useful for deriving new pluripotent cell lines. Accordingly, a further aspect of the invention provides a method of deriving a pluripotent cell from a blastocyst, comprising:-

(1) obtaining a blastocyst;

(2) culturing the blastocyst in the presence of a MEK inhibitor and an antagonist of an FGF receptor, to obtain an inner cell mass;

(3) dissociating the inner cell mass;

(4) isolating a cell or cells from the dissociated inner cell mass; and

(5) culturing the isolated cell or cells in the presence of a MEK inhibitor and an antagonist of an FGF receptor.

The invention also includes kits comprising first and second containers, the first containing a MEK inhibitor and the second containing an antagonist of an FGF receptor. The kit may also comprise other containers and/or components as described herein.

Further aspects of the invention provide use of a MEK inhibitor and an antagonist of an FGF receptor in promoting self-renewal of pluripotent stem cells, especially pluripotent stem cells expressing Nanog. A related aspect provides a method of expanding a stem cell population, comprising culturing the stem cells in the presence of a MEK inhibitor and an antagonist of an FGF receptor.

A number of advantages of the invention are described above or apparent. Cell culture components may be identified which are relatively non-toxic and cell permeable. The MEK inhibitors, GSK3 inhibitors and FGFR antagonists used in specific embodiments of the invention can be purified easily, especially compared to, say, purification of protein cytokines. Recombinant proteins can be expensive to make and the small molecule medium components may be more cheaply produced and more stable in storage, with a wider effective concentration range.

Specific embodiments set out below used a combination of CHIR 99021, PD184352 and, optionally, SU5402 in a serum-free, fully defined medium and gave improved self renewal of mouse ES cells with very little differentiation. It is occasionally reported when culturing ES cells in the presence of BMP that there is some neurogenesis. This was not seen in the examples of the invention.

The invention is now further described in specific examples, illustrated by drawings in which:

Fig. 1 shows analysis of the effect of PD184352 in the formation of pluripotent ES-NS hybrid colonies. (A-C)- FACS analysis for red and green fluorescence of RHxNS TGFP fusions. (A) Fusion mixture 24 hours after PEG treatment; (B) Purity check of FACS sorted hybrids gated in A. (C) Hybrids sorted in A were plated and the formed colonies were scored as percentage of colonies per plated hybrid. These scores take into account the purity of the FACS sorted cells. (D) Summary of data. (E) Examples of hybrid colony morphology.

Fig 2 shows mouse ES cells derived and maintained according to the invention and shows high efficiency of chimera contribution by these ES cells;

Fig 3 shows passage 4 mouse ES cells grown in accordance with the invention; and

Fig 4 shows mouse ES cells, grown in accordance with the invention, are Oct4 positive.

In the examples the term 2i medium or 2i is used to indicate medium comprising a MEK inhibitor and an antagonist of an FGF receptor. The term 3i medium or 3i is used to indicate medium comprising a MEK inhibitor, a GSK3 inhibitor and an antagonist of an FGF receptor.

EXAMPLES

GSK-3β inhibitors, MEK Inhibitors, culture medium and ES cell self-renewal

Mouse and human ES cells were grown under various conditions, using N2B27 medium unless otherwise stated and in the presence or absence of the GSK-3β inhibitors CHIR99021, AR-AO144-18, SB216763 and SB415286 and the MEK inhibitor PD184352.

Preparation of N2B27 medium:

N2 100× stock solution. For 10ml: mix 1ml insulin (final concentration 2.5mg/ml) with 1ml apo-transferrin (final concentration 10mg/ml), 0.67ml BSA (final concentration 5mg/ml), 33µl progesterone (final concentration 2µg/ml), 100µl putrescine (final concentration 1.6mg/ml), 10µl sodium selenite (final concentration 3µM) and 7.187ml DMEM/F12. Store at 4°C and use within 1 month.

DMEM/F12-N2 medium: to 100ml of DMEM/F12, add 1ml of N2 100× stock solution. The final concentration of each component of N2 in the DMEM/F12 medium is: insulin, 25µg/ml; apo-transferrin, 100µg/ml; progesterone, 6ng/ml; putrescine, 16µg/ml; sodium selenite, 30nM; BSA 50µg/ml. Store at 4°C and use within 1 month.

Neurolbasal/B27 medium: to 100ml of Neurolbasal™ Medium, add 2ml of B27 and 0.5-1ml of 200mM L-glutamine. Store at 4°C and use within 1 month.

N2B27 medium: mix DMEM/F12-N2 medium with Neurolbasal/B27 medium in the ratio of 1:1. Add β-mercaptoethanol to a final concentration of 0.1mM from the 0.1M stock. Store at 4°C and use within 1 month.

Example 1

In serum-free medium a MEK inhibitor plus a GSK-3β inhibitor was sufficient to sustain mouse ES cell self-renewal in both (1) N2B27 medium, and (2) fully defined medium (DMEM/F12-N2) – data not shown. Self renewal of ES cells was improved further in medium containing a MEK inhibitor, a GSK-3β inhibitor and LIF (data not shown).

Example 2

It was shown that PD184352, an inhibitor of MEK, increases the levels of Nanog in ES cells (data not shown). In addition, it was shown that Nanog -/- ES cells treated with PD184352 failed to show enhancing of ES cell self-renewal. In fact, these cells differentiated (data not shown). This demonstrated that the enhancing of ES self-renewal phenotype by PD184352 is mediated by Nanog.

The effect of PD184352 in reprogramming was also investigated by determining the conversion of NS cells to pluripotency in the context of cell fusion.

RH ES cells, which express constitutively the dsRed fluorescent protein and hygromycin resistance, were fused to foetal derived Neural Stem cells (NS TGFP) that express the fusion protein TauGFP linked via an IRES to puromycin resistance. In one of the fusions RH cells were treated for 3 days prior and after fusion with 3μM PD184352. In the control no PD184352 was added. Treated and untreated primary hybrids were sorted 24 hours after fusion and then plated (Figure 1A-C). Hygromycin and puromycin selection were added to the ES medium 3 days later. Colonies expressing dsRed2 and GFP fluorescence and exhibiting ES cell morphology were scored (Figure 1D and E). Results showed that PD184352 enhanced ES-NS hybrid colony formation by 45-fold. Interestingly, the percentage of hybrid colonies formed per plated hybrid in PD184352 treated RH cells was just 2-fold lower compared to Nanog overexpressing ES cells (2.25% vs 4%). This result shows that PD184352 not only enhances ES cell self-renewal but also enhances reprogramming in the cell fusion context. This effect is likely to be

mediated by the increased levels of Nanog in treated RH cells. Accordingly, if Nanog is endogenously expressed then the MEK inhibitor can be used to upregulate Nanog and achieve associated effects, such as increased reprogramming.

Example 3

Human ES cells were cultured in media supplemented with the GSK-3 inhibitor CHIR99021 and the MEK inhibitor PD184352.

The addition of LIF to the culture media further improved propagation of the cells (data not shown).

Example 4

Mouse ES cells were cultured in media supplemented with the GSK-3 inhibitor CHIR99021 and the MEK inhibitor PD184352.

The addition of LIF to the culture media further improved propagation of the cells (data not shown).

Example 5

Mouse and human ES cells were grown in medium containing CHIR99021, PD184352 and SU5402, prepared as follows:-

Concentrations of the three inhibitors / antagonist:

Compound	**Initial concentration**	**Dilutions**	**Final Concentration when added to media**
CHIR99021	10mM Store at -20 >1yr	Aliquot stock in 20ul aliquots. Initial 1:10 dilution with N2B27 media = 1mM. Store at 4°C. Add diluted stock to	3μM This concentration was used for all

		media at 1:333 to make 3μM final.	cell lines
PD184352	10mM Store at -20 >1yr	Aliquot stock in 10ul aliquots. Initial 1:100 dilution in N2B27 = 1ml of 100uM, store at 4°C. Add to media at 1:125 for 0.8μM final.	0.8μM Some cell lines were grown in concentrations varying in the range = 0.5 – 1μM
SU5402	5mM Store at -20 >1yr	Initial 1:10 dilution = 0.5mM in N2B27. Add to media at 1:250 for final concentration of 2μM	2μM Some cell lines may need to be optimised, range = 1 – 5μM

Media:

Preparation of DMEM/F12- N2 Medium

To 100ml of DMEM/F12 (Gibco 42400-010) add 1ml of N2 100x stock solution. The final concentration of each component of N2 in the DMEM/F12 medium is:

Insulin 25μg/ml	Putrescine 16μg/ml	Transferrin 100μg/ml
Sodium Selenite 30nM	Progesterone 6ng/ml	BSA 50μg/ml

Preparation of Neurobasal/B27:

To 100ml Neurobasal medium (Gibco 21103-049) add 2ml of B27 (Gibco 17504-044) and 1-2M L-glutamine (TC stores 1:100)

Preparation of N2 B27 medium:

Mix DMEM/F12-N2 medium with Neurobasal/B27 medium at the ratio of 1:1.
The media was used to dilute all compounds and grow the cells.

The medium was used for maintenance of human ES cells and for derivation and maintenance of ES cells from 129 strain mice, and also for derivation of ES cells from the non-permissive mouse strains CBA and C56/BL6..

Example 6

Mouse ES cells were cultured in the presence of an inhibitor of the FGF receptor and a MEK inhibitor. Selective pharmacological inhibitors SU5402 and PD184352 were used to inhibit FGF receptor tyrosine kinase and activation of Erk1/2 via MEK1/2, respectively. We found that addition of either inhibitor is sufficient for robust ES cell propagation in N2B27 medium containing LIF without provision of BMP4 (data not shown). Undifferentiated cultures can be continuously passaged in these conditions while retaining expression of the pluripotency markers Oct4, Nanog, and Rex1. Neural commitment does not occur despite much lower expression of Id genes than in cultures maintained with LIF plus BMP.

ES cells plated in N2B27 medium without added LIF, conditions that normally elicit efficient neural commitment, remain Oct4 positive and Sox1 negative for several days if either SU5402 or PD184352 are added (data not shown). However, these cells invariably differentiate and/or die after passaging. To reduce potential toxic side effects we used 2.5 fold lower doses and combined the two inhibitors together. In N2B27 with 0.8μM PD184352 plus 2μM SU5402, some differentiation is observed initially, but ES cells persist and expand after passage (data not shown). Viability is lower and population doubling time slower in this two inhibitor (2i) condition than in the presence of LIF, but differentiation is effectively restrained. This finding suggests that the minimal requirements for ES cell self-renewal may be to deflect differentiation signals emanating from FGF receptor and Erk signaling while avoiding compromise to cell growth and viability.

Example 7

We reasoned that reduced growth of ES cells in 2i media could be due to increased activity of glycogen synthase kinase 3 (GSK-3) consequent to release of inhibitory phosphorylation by Rsk downstream of pErk. CHIR99021 is a well-characterised highly selective small molecule inhibitor of GSK-3 that does not cross react with cyclin-

dependent kinases (CDKs) at concentrations that completely block GSK-3 activity. When added to cultures in the presence of serum we found that CHIR99021 (3μM) actually promotes differentiation, even in the presence of LIF. In serum-free N2B27 medium the differentiation response is reduced and some colonies appear morphologically undifferentiated for several days. However, undifferentiated cells do not persist after passaging. Similar results were obtained with two other widely used GSK-3 inhibitors, SB216763 and SB415286, although both appeared somewhat toxic to ES cells.

However, when CHIR99021 is combined with 2i the differentiation response is lost entirely. Furthermore, CHIR99021 modulated the response to 2i such that ES cells grew as compact three dimensional colonies rather than flattened monolayers typically seen in LIF plus serum/BMP or in 2i. Differentiation was negligible in the three inhibitors (3i) and ES cells propagated rapidly. Most importantly undifferentiated colonies grew up at high efficiency after passaging. Derivatives of two independent parental ES cell lines, E14Tg2a and CGR8 showed robust long term expansion in 3i with little or no overt differentiation (data not shown). They express Oct4, Nanog and Rex1 and do not exhibit appreciable expression of lineage commitment markers, Gata4, Sox1, or brachyury (data not shown). In bulk culture ES cells expand with a comparable doubling rate in 3i as in LIF plus BMP, and the proportion of Oct4-GFP positive undifferentiated cells remains over 90%.

Thus, 3i medium can be used to culture ES cells without differentiation in the absence of serum or added cytokines.

Example 8

A rigorous test of the sufficiency of a culture formulation to sustain ES cell self-renewal is formation of undifferentiated colonies by individual cells. After single cell deposition, cloning efficiency in N2B27 plus 3i is 25% (98/384), higher than with LIF plus BMP (11%, 23/192) - data not shown. These colonies express Oct4-GFP and are passageable

as undifferentiated ES cells. Thus, medium comprising a MEK inhibitor, an inhibitor of the FGF receptor and a GSK3 inhibitor is able to sustain the formation of undifferentiated ES cell colonies derived from single cells.

Example 9

We examined whether 3i was adequate for the derivation of new ES cells directly from embryos or reflected an adaptation of established lines. Blastocysts from the permissive 129 strain were plated directly in N2B27 plus 3i on gelatin-coated plastic and cultured for 5 days. After subsequent dissociation and replating of the inner cell mass, ES cell colonies were obtained from 7 of 12 embryos. Three of these were expanded and injected into blastocysts. All gave high rates of chimaerism and germline transmission (Table 1). Subsequently we have derived multiple ES cells from C57BL/6 and non-permissive CBA and MF1 strains indicating that 3i facilitates the transition from epiblast to ES cell. We conclude that 3i liberates ES cells from requirements for exogenous LIF and BMP/serum without selection or compromise to developmental potency.

TABLE 1 - Contribution of ES cells derived in 3i to chimaeras and production of germline offspring

Cell line	No. embryos injected	No. liveborn pups	No. chimaeras*	No. test-mated	No. transmitting*
CPS1	64	16	12	8 (5m, 3f)	3f[#]
CPS2	21	5	4	3 (1m, 2f)	2f[#]
CPS3	20	15	11	4 (3m, 1f)	2m

* Chimaerism and transmission of the 129/Ola ES cell genome detected by coat colour
[#] ES cells assumed to be XX.

Thus, ES cells are maintained in a combination of a GSK3 inhibitor and a MEK inhibitor, a MEK inhibitor and an antagonist of an FGF receptor or, optionally, a GSK3 inhibitor, a MEK inhibitor and an antagonist of an FGF receptor and the invention also provides culture methods and media therefor.

Claims

1. A culture medium, comprising a MEK inhibitor and a GSK3 inhibitor.

2. A culture medium according to claim 1, further comprising an antagonist of an FGF receptor.

3. A culture medium according to claim 1 or 2, wherein the MEK inhibitor is a MEK1 inhibitor.

4. A culture medium according to any preceding claim, wherein the MEK inhibitor is selected from PD184352 and PD98059.

5. A culture medium according to any preceding claim, wherein the GSK3 inhibitor is an inhibitor of GSK-3β.

6. A culture medium according to any preceding claim, wherein the GSK3 inhibitor is selective for GSK3 over cdc2 and/or erk2.

7. A culture medium according to claim 6, wherein the GSK3 inhibitor is at least 100 fold selective for GSK3 over cdc2.

8. A culture medium according to claim 6, wherein the GSK3 inhibitor is at least 200 fold selective for GSK3 over cdc2.

9. A culture medium according to any preceding claim, wherein the GSK3 inhibitor is CHIR99021.

10. A culture medium according to any preceding claim, further comprising a gp130 agonist.

11. A culture medium according to claim 10, wherein the gp130 agonist is LIF, CNTF, cardiotrophin, oncostatin M, IL-6 plus sIL-6 receptor or hyper IL-6.

12. A culture medium according to claim 10, wherein the gp130 agonist is (a) LIF, (b) sIL-6R and IL-6, or (c) hyper IL-6.

13. A culture medium according to any of claims 2 to 12, wherein the FGF receptor antagonist is an antagonist of FGFR1.

14. A culture medium according to claim 13, comprising SU5402.

15. A culture medium according to claim 13, comprising PD173074.

16. A culture medium according to any preceding claim, comprising an inhibitor of apoptosis.

17. A culture medium according to any preceding claim, comprising N2 medium and/or B27 medium.

18. A culture medium according to any preceding claim comprising PD184352, CHIR99021 and SU5402.

19. A human ES culture medium according to any preceding claim.

20. A mouse ES cell culture medium according to any of claims 1 to 18.

21. Use of a MEK inhibitor and a GSK3 inhibitor in manufacture of a culture medium for pluripotent cells.

22. Use of a MEK inhibitor, a GSK3 inhibitor and an antagonist of an FGF receptor in manufacture of a culture medium for pluripotent cells.

23. Use according to claim 21 or 22 wherein the medium is for culture of mouse ES cells.

24. Use according to claim 21 or 22, wherein the medium is for culture of human ES cells.

25. Use according to claim 21 or 22 wherein the medium is for culture of rat pluripotent cells.

26. A method of culture of pluripotent cells so as to promote self renewal, comprising maintaining the cells in medium according to any of claims 1 to 18.

27. A method according to claim 26, wherein the medium is free of serum and free of serum extract.

28. A method according to claim 26 or 27, wherein the cells are mouse cells.

29. A method according to claim 26 or 27, wherein the cells are human cells.

30. A method according to claim 26 or 27 wherein the cells are rat cells.

31. A method of culture of ES cells, comprising the steps of:-

- maintaining the ES cells in a pluripotent state in culture, optionally on feeders,
- passaging the ES cells at least once;
- withdrawing serum or serum extract (if present) from the medium and withdrawing the feeders (if present), so that the medium is free of feeders, serum and serum extract; and
- subsequently maintaining ES cells in a pluripotent state in the presence of a MEK inhibitor and a GSK3 inhibitor.

32. A method of culture according to claim 31, wherein the cells are maintained in a pluripotent state in the presence of a MEK inhibitor, a GSK inhibitor and an activator of a gp130 downstream signalling pathway.

33. A method according to claim 31, wherein the cells are maintained in a pluripotent state in the presence of a MEK inhibitor, a GSK inhibitor and an FGF receptor antagonist.

34. A method according to any of claims 31 to 33, wherein the cells are mouse cells.

35. A method according to any of claims 31 to 33, wherein the cells are human cells.

36. A method of obtaining a transfected population of ES cells, comprising:-
- transfecting ES cells with a construct encoding a selectable marker;
- plating the ES cells;
- culturing the ES cells in the presence of a MEK inhibitor and a GSK3 inhibitor and
- selecting for cells that express the selectable marker.

37. A method according to claim 36, wherein the ES cells are cultured in the presence of a MEK inhibitor, a GSK inhibitor and an activator of a gp130 downstream signalling pathway.

38. A method according to claim 36, wherein the ES cells are cultured in the presence of a MEK inhibitor, a GSK inhibitor and an FGF receptor antagonist.

39. A method according to any of claims 36 to 38, wherein the cells are mouse cells.

40. A method according to any of claims 36 to 38, wherein the cells are human cells.

41. A cell culture medium that is free of serum and serum extract and comprises:-
- basal medium;

- a MEK inhibitor;
- a GSK3 inhibitor; and
- an iron-transporter.

42. A culture medium according to claim 41, further comprising an activator of a gp130 downstream signalling pathway.

43. A culture medium according to claim 41 or 42, further comprising an antagonist of an FGF receptor.

44. A culture medium according to any of claims 41 to 43, further comprising insulin, albumin and transferrin.

45. A culture medium according to any of claims 41 to 44, further comprising an inhibitor of apoptosis.

46. A method of deriving a pluripotent cell from a blastocyst, comprising:-

(1) obtaining a blastocyst;

(2) culturing the blastocyst in the presence of a MEK inhibitor and a GSK3 inhibitor, to obtain an inner cell mass;

(3) dissociating the inner cell mass;

(4) isolating a cell or cells from the dissociated inner cell mass; and

(5) culturing the isolated cell or cells in the presence of a MEK inhibitor and a GSK3 inhibitor.

47. A method according to claim 46, wherein the isolated cell or cells are cultured in the presence of an activator of gp130 downstream signalling, a MEK inhibitor and a GSK3 inhibitor.

48. A method according to claim 46, wherein the isolated cell or cells are cultured in the presence of an antagonist of an FGF receptor, a MEK inhibitor and a GSK3 inhibitor.

49. A method according to any of claims 46 to 48, comprising culturing the blastocyst in LIF for a period of from 2 to 4 days.

50. A kit, comprising first and second containers, the first containing a GSK3 inhibitor and the second containing a MEK inhibitor.

51. A kit according to claim 50, further comprising a third container containing an antagonist of an FGF receptor.

52. A kit according to claim 37, wherein the GSK3 inhibitor, the MEK inhibitor and the FGFR antagonist are as defined in claims 3 to 9 or 13 to 15.

53. A kit according to any of claims 50 to 52, comprising a further container containing an activator of gp130 downstream signalling.

54. A kit according to claim 53, wherein the gp130 agonist is (a) LIF, (b) sIL-6R and IL-6, or (c) hyper IL-6.

55. Use of a MEK inhibitor and a GSK3 inhibitor in promoting self-renewal of pluripotent stem cells.

56. Use of a MEK inhibitor, a GSK3 inhibitor and an antagonist of an FGF receptor in promoting self-renewal of pluripotent stem cells

57. A method of expanding a stem cell population, comprising culturing the stem cells in the presence of a MEK inhibitor and a GSK3 inhibitor.

58. A method of expanding a stem cell population, comprising culturing the stem cells in the presence of a MEK inhibitor, a GSK3 inhibitor and an antagonist of an FGF receptor.

59. Use of a MEK inhibitor and a GSK3 inhibitor in promoting self-renewal of pluripotent stem cells expressing Nanog.

60. Use of a MEK inhibitor, a GSK3 inhibitor and an antagonist of an FGF receptor in promoting self-renewal of pluripotent stem cells expressing Nanog.

61. A culture medium, comprising a MEK inhibitor and an antagonist of an FGF receptor.

62. Use of a MEK inhibitor and an antagonist of an FGF receptor in manufacture of a culture medium for pluripotent cells.

63. A method of culture of pluripotent cells so as to promote self renewal, comprising maintaining the cells in medium comprising a MEK inhibitor and an antagonist of an FGF receptor.

64. A method of culture of ES cells, comprising the steps of:-

- maintaining the ES cells in a pluripotent state in culture, optionally on feeders,
- passaging the ES cells at least once;
- withdrawing serum or serum extract (if present) from the medium and withdrawing the feeders (if present), so that the medium is free of feeders, serum and serum extract; and
- subsequently maintaining ES cells in a pluripotent state in the presence of a MEK inhibitor and an inhibitor of an FGF receptor.

65. A method of obtaining a transfected population of ES cells, comprising:-

- transfecting ES cells with a construct encoding a selectable marker;
- plating the ES cells;
- culturing the ES cells in the presence of a MEK inhibitor and an FGF receptor antagonist and
- selecting for cells that express the selectable marker.

66. A cell culture medium that is free of serum and serum extract and comprises:-
- basal medium;
- a MEK inhibitor;
- an antagonist of an FGF receptor; and
- an iron-transporter.

67. A method of deriving a pluripotent cell from a blastocyst, comprising:-
(1) obtaining a blastocyst;
(2) culturing the blastocyst in the presence of a MEK inhibitor and an antagonist of an FGF receptor, to obtain an inner cell mass;
(3) dissociating the inner cell mass;
(4) isolating a cell or cells from the dissociated inner cell mass; and
(5) culturing the isolated cell or cells in the presence of a MEK inhibitor and an antagonist of an FGF receptor.

68. A kit comprising first and second containers, the first containing a MEK inhibitor and the second containing an antagonist of an FGF receptor. The kit may also comprise other containers and/or components as described herein.

69. Use of a MEK inhibitor and an antagonist of an FGF receptor in promoting self-renewal of pluripotent stem cells.

70. Use of a MEK inhibitor and an antagonist of an FGF receptor in promoting self-renewal of pluripotent stem cells expressing Nanog.

71. A method of expanding a stem cell population, comprising culturing the stem cells in the presence of a MEK inhibitor and an antagonist of an FGF receptor.