DESCRIPTION

CELL CULTURE KIT, SCREENING METHOD, AND METHOD OF MANUFACTURING CELL CULTURE KIT

Technical Field

[0001]

The present invention relates to a cell culture kit in which living cells are cultured, a screening method, and a manufacturing method thereof.

Background Art

[0002]

A technique of using cells isolated from a tissue in testing or examination is an essential method in the biotechnology-related fields. It is widely used in diagnosing a disease or pathological condition, searching for a new drug and evaluating the efficacy of a drug, or in animal inspection, plant inspection, testing for environmental pollutants, and so on. Thus, cells and the like used in the biotechnology field have been greatly diversified.

[0003]

The isolated cells are sometimes used immediately for testing, but in many cases, the cells are cultured in a culture dish or a test tube. Various examinations are carried out using the cultured cells. Cell lines in culture for use in cell culture tests are required to show drug susceptibility and toxic reaction that are similar to those obtained in a test performed in a living body, that is, a so-called in vivo test. In short, it is necessary to be able to construct an intercellular network regularly arranged on the surface of a cell culture chamber. Further, the cell lines in culture for use in cell culture tests are extremely expensive, so an improvement in survival rate and proliferation rate of cells is desired. In other words, an in vivo-like cell function is required in a cell culture chamber. Furthermore, an isolation operation to obtain primary cells is complicated, and the cell lines in culture for use in cell culture tests are expensive, so a test method using a small

number of cells is desired.

[0004]

Recently, discontinuation of development in the clinical testing phase has been an issue. This is due to an animal species difference in the pharmacokinetics study phase. Heretofore, in pharmacokinetics studies in the preclinical phase, drug disposition has been predicted by using an animal such as a rat, a dog or a monkey. However, it has become evident that the prediction is virtually invalid in a clinical testing using a human. Therefore, in the prediction of pharmacokinetics or the like for humans, using a human sample is the most effective and convenient way, and it is important for conducting efficient drug development and safe clinical testing.

[0005]

In the pharmacokinetics study that examines drug disposition, absorption, metabolism and excretion in the liver are mainly examined, and a human sample to be used is liver slices, liver cells, liver microsomes or the like. Among those, the liver slices are not easily obtainable, and the liver microsomes can be used only for a metabolism test with limited metabolic enzymes. Thus, use of the liver cells is considered to be the most effective.

[0006]

In screening, a culture dish to be used is a petri dish made of resin or a 6-well, 12-well, 48-well or 96-well plate. In general, the size of the entire plate is substantially the same, and as the number of wells increases, the size of one well decreases. A single well corresponds to a single culture dish. With the recent trend toward miniaturization, a 384-well plate having a number of culture dishes with a small diameter has also come to be used. Therefore, culture dishes which are suitable for an intended screening method come to be used. Bottoms of these culture dishes have a flat plate shape, and each of the bottom surfaces is used as a culture surface.

[0007]

However, if a hitherto-used culture dish is used for culture of tissue cells, there are cases where the original function disappears and

dedifferentiation occurs and where undifferentiated cells do not differentiate, which raises an issue that a target cell function is not expressed. For example, if fresh human liver cells are cultured on a normal flat plate, the function of metabolic enzymes when isolated is significantly lowered in one day or so, and therefore a drug metabolism test is conducted in four hours from seeding the cells onto the plate in some cases. There is thus a problem that it is impossible to make use for a test with long-hours culture and a problem that it is impossible to investigate long-hours metabolic stability.

[0008]

To overcome the above problems, an attempt to coat a surface of a culture chamber with a biological material (glycoprotein, protein etc.) of human or animal origin (see Patent Literature 1), and an attempt to culture in polymer gel (see Patent Literature 2) have been made.

[0009]

However, in the method disclosed in Patent Literature 1, there are problems such that the biological material as coating is special and high cost, it is difficult to form a uniform cell aggregate in a culture chamber, and the in vivo function cannot be maintained over a long period of time. In the method disclosed in Patent Literature 2 also, there are problems such that the size of a cell aggregate cannot be controlled, microscopic observation is not easy, and operability is complicated as a screening substrate. Further, because a commercially available dish or plate is used as a supporting chamber in both of the above methods, efficient screening with the minimum number of cells required is difficult.

[0010]

Citation List

Patent Literature

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 8-319317

Patent Literature 2: Japanese Unexamined Patent Application

Summary of Invention

Technical Problem

[0011]

As described above, for efficient drug development and safe clinical testing, many tests using human liver cells, nervous system, an intestinal epithelial system, and the like have been conducted in terms of drug toxicity, metabolism, and drug efficacy. In many cases, cell lines and primary cultured cells are used in these tests. In the case of cell lines, there is a problem that in vivo functions are not reflected. On the other hand, primary cultured cells can reflect in vivo functions, but the individual difference becomes a problem. To overcome the problem of individual difference, it has been studied to use living cells including floating cells which include liver cells from various donors, and to obtain averaged data. However, there is a problem that the life-span of floating cells is short, which makes it impossible to use the floating cells for a test over a long period of time.

[0012]

The present invention has been made to solve the above-mentioned problems, and therefore has an object to provide a cell culture kit in which living cells from various donors are cultured, a screening method, and a manufacturing method thereof.

Solution to Problem

[0013]

An aspect of a cell culture kit according to the present invention is a cell culture kit including a cell culture plate and living cells cultured thereon. The cell culture plate includes a plurality of micro spaces, and living cells derived from various donors are adhered to surfaces of the plurality of micro spaces. This makes it possible to provide a kit for screening in which living cells derived from various donors are adhered to a single cell culture plate.

[0014]

The living cells derived from various donors may include two or more types of cells. This makes it possible to reproduce a tissue-like structure formed by various types of living cells.

[0015]

Specifically, the living cells derived from various donors or living cells derived from a single donor are adhered to each of the plurality of micro spaces.

For example, living cells derived from various donors are adhered to at least two adjacent micro spaces. Alternatively, living cells derived from a single donor are adhered to at least two adjacent micro spaces.

[0016]

Further, it is preferred that the plurality of micro spaces have dimensions to allow a cell population of a three-dimensional structure to be isolated, the cell population being obtained by culture of a desired number of cells.

[0017]

It is preferred that the living cells be seeded in the plurality of micro spaces at a cell seeding density of 1×10^2 to 1×10^6 cells/cm^2, more preferably at a cell seeding density of 1×10^4 to 1×10^6 cells/cm^2. It is preferred that a cell mass having the living cells accumulated therein be formed in each of the plurality of micro spaces, more specifically, it is preferred that the cell mass have a diameter of 30 to 200 μm.

[0018]

It is preferred that the living cells be one of tissue precursor cells, tissue stem cells, cells differentiated from ES cells, and cells differentiated from iPS cells.

Alternatively, it is preferred that the living cells include liver cells. It is more preferred that the liver cells be one of tissue precursor cells, tissue stem cells, cells differentiated from ES cells, and cells differentiated from iPS cells, and that the living cell including the liver cells be isolated from hepatic tissues of various donors.

[0019]

Further, an aspect of a screening method according to the present invention is a screening method for evaluating drugs by using above-described cell culture kit.

[0020]

Furthermore, an aspect of a method of manufacturing a cell culture kit according to the present invention is a method of manufacturing a cell culture kit which includes a culture plate including a plurality of micro spaces and living cells cultured thereon. The method of manufacturing a cell culture kit includes: seeing living cells derived from various donors in the plurality of micro spaces; and culturing the seeded living cells.

Advantageous Effects of Invention

[0021]

According to the present invention, it is possible to provide a cell culture kit in which living cells of various donors are cultured, a screening method, and a method of manufacturing a cell culture kit.

Brief Description of Drawings

[0022]

Fig. 1 is a plane view showing a structure of a cell culture chamber according to an embodiment;

Fig. 2 is a cross-sectional view along the line II-II showing the structure of the cell culture chamber according to an embodiment;

Fig. 3 is a plane view showing another structure of a cell culture chamber according to an embodiment;

Fig. 4 is a cross-sectional view along the line IV-IV showing another structure of the cell culture chamber according to an embodiment;

Fig. 5 is a plane view showing still another structure of a cell culture chamber according to an embodiment;

Fig. 6 is a cross-sectional view along the line VI-VI showing still another structure of the cell culture chamber according to an

embodiment;

Fig. 7 is a view showing an exemplary cell culture kit in which a plurality of cell culture chambers are arranged;

Fig. 8 is a view showing an exemplary state in which living cells are cultured in a plurality of microchambers;

Fig. 9 is a view showing another exemplary state in which living cells are cultured in a plurality of microchambers;

Fig. 10 is a view showing still another exemplary state in which living cells are cultured in a plurality of microchambers;

Fig. 11A is a photograph showing a result of morphology observation on the 1st day of culture of an example;

Fig. 11B is a photograph showing a result of morphology observation on the 4th day of culture of the example;

Fig. 11C is a photograph showing a result of morphology observation on the 7th day of culture of the example;

Fig. 11D is a photograph showing a result of morphology observation on the 14th day of culture of the example;

Fig. 11E is a photograph showing a result of morphology observation on the 21st day of culture of the example;

Fig. 11F is a photograph showing a result of morphology observation on the 35th day of culture of the example;

Fig. 12 is a photograph showing a result of morphology observation on the 14th day of culture of a comparative example;

Fig. 13 is a photograph showing measurement results of primary drug-metabolizing enzyme and albumin secretory capability of an example;

Fig. 14 is a photograph showing an immunostaining result (culture for 28 days) of an example; and

Fig. 15 is a photograph showing an immunostaining result (culture for 30 days) of a comparative example.

Description of Embodiments

[0023]

A cell culture kit according to the present invention includes a

cell culture plate and living cells cultured thereon, and uses a plurality of microchambers which are included in the culture plate. Living cells derived from various donors are adhered to surfaces of the plurality of microchambers. Since the living cells are cultured so as to maintain cell functions, it is necessary to use suitable microchambers, which are units for culturing the living cells. Examples of the cell culture chamber to be used for the cell culture kit according to the present invention are given below.

[0024]

A cell culture chamber has a concave-convex pattern, i.e., a plurality of microchambers formed therein. This permits cells to grow in three dimensions, like in a living body, and also permits cells to be cultured in aggregated form with no variation in each microchamber. The height of side walls (convex portions) for partitioning the microchambers is optimized, thereby making it possible to culture aggregated living cells (for example, a mass of liver cells) exclusively within the microchambers. Note that the term "micro space" refers to a space formed by a microchamber, more specifically to a space formed by a concave-convex pattern formed on a plane surface. Hereinafter, the microchamber and the micro space are not particularly distinguished from each other.

[0025]

The dimensions of the microchambers each surrounded by the side walls have to be set within the optimum range for culturing cells. If the bottom area of each microchamber is too large, cells are thinly elongated and fail to show a three-dimensional structure, as in the culture on a flat plate. If, on the other hand, the bottom area of each microchamber is too small, it cannot accommodate cells. Accordingly, the dimensions of the space structure are preferably in a range capable of containing one or a plurality of cells according to cell species to be cultured. In the case of forming the mass of liver cells in which a plurality of cells is accumulated, the dimensions are preferably in a range capable of containing the mass of liver cells.

[0026]

The height of each side wall has to be set within the optimum range for preventing the cells cultured in the microchambers from moving to the adjacent microchambers. If the height of each side wall is too low, the cells run on the side wall, and thus such side wall is unsuitable for culture. If the height of each side wall is too high, the production thereof is difficult and material diffusion becomes difficult, leading to a deterioration of the culture environment. Therefore, the height of each side wall is preferably in the range capable of continuously and stably culturing cells, which are arranged in the microchambers according to cell species, within the microchambers.

[0027]

In addition, openings are formed in the side walls to obtain a structure in which the plurality of microchambers communicates with each other, thereby making it possible to supply oxygen and nutrients to cells and remove waste products from the cells effectively. Note that the height of the side walls, the dimensions of the microchambers, and the width of the openings are appropriately set according to cell species to be cultured, thereby enabling application to various culture systems.

[0028]

In this specification, the term "living cells" refers to cells (primary cultured cells) which are isolated from a living body tissue and which are not passaged. The living cells include fresh cells and frozen cells. The living cells also include cell lines, other ES cells (Embryonic Stem cells), and so on.

[0029]

As the living cells, one or more types of cells are preferably selected from among liver cells (parenchymal liver cells), hepatic stellate cells, fat cells, skeletal muscle cells, cardiac muscle cells, smooth muscle cells, cartilage cells, bone cells, nerve cells, glia cells, Schwann cells, beta cells of pancreas, epidermal cells, vascular endothelial cells, fibroblast, and mesenchymal cells. These cell species may be primary cultured cells, tissue precursor cells, tissue stem cells, cells differentiated from ES cells, or cells differentiated

from iPS cells.

[0030]

Embodiment

Hereinafter, an embodiment of the present invention is described. However, the present invention is not limited to the following embodiment. Further, to clarify the explanation, the following description and the drawings are appropriately simplified.

[0031]

First, a cell culture chamber for use in a cell culture kit according to an embodiment will be described, and subsequently, an exemplary structure of the cell culture kit will be described. To begin with, an exemplary structure of the cell culture chamber will be described with reference to Figs. 1 and 2. Fig. 1 is a plane view showing the structure of the cell culture chamber according to this embodiment, and Fig. 2 is a cross-sectional view along the line II-II in Fig. 1. As shown in Fig. 1, a cell culture chamber 10 includes microchambers 11, side walls 12, and openings 13. The plurality of side walls 12 is formed in a net shape on the culture surface of the cell culture chamber 10, and spaces surrounded by the side walls 12 serve as the microchambers 11. Additionally, each of the openings 13 is formed at a central portion of each side of the side walls 12 which are formed on four sides of each of the microchambers 11.

[0032]

Fig. 1 shows a width "a" of the bottom of each of the microchambers 11, a width "b" and a height "c" of each of the side walls 12 for partitioning the microchambers 11, and a width "d" of each of the openings 13 for allowing communication between the microchambers 11 adjacent to each other. The term "bottom area" of the present invention refers to a projected area which is formed when parallel light is irradiated to the bottom of the chamber from above in the direction perpendicular to the horizontal plane of the microchmaber opening (the same plane as the top surfaces of the side walls 12). For example, if the bottom of the microchamber is U-shaped, the bottom area has a shape formed by projecting parallel light incident on the

bottom from above in the direction perpendicular to the opening plane. In the case of a circle or an ellipse, a major axis of a projected bottom is a distance between intersections of a long axis which runs through the center of gravity thereof and the circumference, and a minor axis of the projected bottom is a distance between intersections of a short axis which runs through the center of gravity thereof and the circumference. In the case of a polygon, the major axis and the minor axis of the projected bottom respectively correspond to a long axis and a short axis of an extrapolated circle or an extrapolated ellipse which is set so as to minimize the difference between areas of the polygon and the extrapolated circle or the extrapolated ellipse and which runs through all vertexes of the polygon. If an extrapolated circle or an extrapolated ellipse which runs through all vertexes of the polygon cannot be traced, the major axis and the minor axis respectively correspond to a long axis and a short axis of an approximate circle or an approximate ellipse which runs through the largest number of vertexes.

[0033]

The bottom shape of each of the microchambers 11 is not particularly limited, and various shapes other than a square, a circle, and a polygon can be employed. In cell culture for reproducing a liver function in vivo, the bottom area is preferably 0.01 mm^2 to 0.1 mm^2. In this case, the major axis of the bottom is preferably 1 to 1.5 times the minor axis thereof. An isotropic shape is more preferably used. If a square is employed, for example, in the case of forming a mass of liver cells having an equivalent diameter of 100 μm, the length of one side thereof is preferably 100 μm to 300 μm.

[0034]

An angle formed between the horizontal plane and the side walls 12 of each of the microchambers 11 should be set to an angle at which cells are prevented from running on the microchambers. Accordingly, 50% or more of an upper portion of a side surface preferably has an angle of 80° to 90°, and more preferably, 85° to 90°.

[0035]

The height "c" of each of the side walls 12 may be arbitrarily set as log as the cells cultured in the microchambers 11 are prevented from running on and moving to the adjacent microchamber 11. In the case of forming a mass of liver cells having an equivalent diameter of 100 μm, the height "c" is preferably 50 μm to 150 μm, for example.

[0036]

The width "d" of each of the openings 13 for allowing communication between the microchambers 11 adjacent to each other is preferably set to a width in which cells are prevented from moving from the microchamber 11, in which the cultured cell is first seeded, to the adjacent microchamber 11. When the equivalent diameter of the cultured cell is 20 μm, for example, the width is preferably 5 to 15 μm. Note that the openings 13 are not necessarily formed. As shown in Figs. 3 and 4, the four sides of each of the microchambers 11 may be entirely surrounded by the side walls 12. Here, Fig. 3 is a plane view showing another structure of the cell culture chamber according to this embodiment, and Fig. 4 is a cross-sectional view along the line IV-IV in Fig. 3.

[0037]

In Fig. 3, the width "a" of the bottom surface of the microchamber 11, and the width "b" and the height "c" of the side wall 12 for partitioning the microchambers 11 are shown. It is necessary to satisfy $3\ \mu m \leq b \leq 15\ \mu m$ and $c/b \geq 2$. If the width "b" of the side wall 12 is more than 15 μm, a cell adheres to the top surface of the side wall, which is unsuited to culture. On the other hand, if the width "b" of the side wall 12 is less than 3 μm, preparation is difficult. If the height of the side wall is too low, a cell goes over the side wall, which is unsuited to culture. If the height "c" of the side wall 12 is less than two times the width "b" of the side wall 12, a cell cultured in the microchamber 11 goes over it and moves to the adjacent microchamber 11. Further, specifically, when human fetal liver cells are layered in a square microchamber with one side of 100 μm, the height "c" of the side wall 12 is preferably 15 μm to 300 μm, and more preferably 50 μm to 150 μm. If the height "c" of the side wall is too high, preparation is

difficult and further the material is hard to diffuse, which degrades the culture environment. The side wall 12 may have a multi-step shape.

[0038]

The cell culture unit may have partitioned spots each made up of a plurality of microchambers required for one screening as shown in Figs. 5 and 6 in order to minimize the number of cells required. For example, in the case of using a microchamber in a square shape with one side of 200 μm and a height of 50 μm which provides a high differentiation efficiency when the minimum number of cells required for screening is about 1000, nine microchambers are required; therefore, by preparing a spot in which the space is partitioned into nine microchambers and providing a plurality of spots, it is possible to perform high-throughput screening that allows simultaneous examination of a plurality of reagents or pharmaceutical agents.

[0039]

Fig. 5 is a plane view showing another structure of a cell culture unit according to the embodiment, and Fig. 6 is a cross-sectional view along line IV-IV in Fig. 5. Fig. 5 shows the side wall 24 that partitions a plurality of microchambers and a partitioned spot 23. The height "d" of the side wall 24 may be set so that the capacity can keep a supernatant fluid such as a culture solution or a reaction solution without drying, and it can be defined appropriately.

[0040]

A method for forming the concave-convex pattern on the cell culture chamber is not particularly limited, but methods such as transfer molding using a mold, three-dimensional stereolithography, precision machining, wet etching, dry etching, laser processing, and electrical discharge machining may be employed. It is preferable to appropriately select these production methods in view of the intended use, required processing accuracy, costs, and the like of the cell culture chamber.

[0041]

As a specific example of the transfer molding method using a mold, a method for forming the concave-convex pattern by resin

molding using a metal structure as a mold may be employed. This method is preferred because it is capable of reproducing the shape of the metal structure on a resin as the concave-convex pattern with a high transcription rate, and because the raw material cost can be reduced by using a general-purpose resin material. Such a method using a mold of a metal structure is superior in terms of low cost and achieving satisfactorily high dimensional accuracy.

[0042]

As methods of producing the metal structure, for example, plating treatment, precision machining, wet etching, dry etching, laser processing, and electrical discharge machining on a resist pattern produced by photolithography or a resin pattern produced by three-dimensional stereolithography may be employed. The methods may be appropriately selected in view of the intended use, required processing accuracy, costs, and the like.

[0043]

As methods of forming the concave-convex pattern on a resin using the metal structure, which is obtained as described above, as a mold, injection molding, press molding, monomer casting, solvent casting, hot embossing, or roll transfer by extrusion molding may be employed, for example. It is preferable to employ injection molding in view of its productivity and transcription property.

[0044]

Materials for forming a cell culture chamber are not particularly limited as long as the materials have self-supporting properties. For example, synthetic resin, silicon, or glass may be employed. A transparent synthetic resin is preferably used as a material in view of costs and cell visibility under microscopical observation. Examples of the transparent synthetic resin include acrylic resins such as polymethylmethacrylate or methyl methacrylate-styrene copolymer, styrene resin such as polystyrene, olefin resin such as cycloolefin, ester resins such as polyethylene terephthalate and polylactic acid, silicone resin such as polydimethylsiloxane, and polycarbonate resin. These resins may contain various additives such as colorant, dispersing

agent, and thickening agent, unless the transparency is impaired.

[0045]

In the cell culture chamber, surface treatment may be performed on the surface side of the concave-convex pattern and a modified layer and/or a coating layer may be formed for the purpose of improving the hydrophilic properties, biocompatibility, cellular affinity, and the like of the chamber surface. A method for forming the modified layer is not particularly limited unless a method with which the self-supporting properties are impaired and a method causing extreme surface roughness of 100 μm or more are employed. Methods, for example, chemical treatment, solvent treatment, chemical treatment such as introduction of a graft polymer by surface graft polymerization, physical treatment such as corona discharge, ozone treatment, or plasma treatment may be employed. In addition, though a method for forming the coating layer is not particularly limited, methods, for example, dry coating such as sputtering or vapor deposition and wet coating such as inorganic material coating or polymer coating may be employed. In order to pour a culture solution without mixing air bubbles therein, it is desirable to impart the hydrophilic properties to the surface of the concave-convex pattern. As a method for forming a uniform hydrophilic membrane, inorganic vapor deposition is preferably employed.

[0046]

When the cellular affinity is taken into consideration, it is more preferable to coat cytophilic proteins such as collagen and fibronectin. In order to uniformly coat a collagen aqueous solution or the like, it is preferable to perform the coating after the above-mentioned hydrophilic membrane is formed. In hepatocyte cultures, in general, it is desirable to culture cells on an extracellular matrix surface by replicating the in vivo environment. Accordingly, it is particularly preferable to dispose an organic film made of extracellular matrix suitable for cultured cells after an inorganic hydrophilic membrane is uniformly formed as described above.

[0047]

In a cell culture method using the cell culture chamber described above, an appropriate number of cells need to be seeded so that the cells are arranged exclusively within the microchambers for culturing cells and that morphologies and functions similar to those of the living body are developed within the space. A cell seeding density of 1.0×10^2 to 1.0×10^6 cells/cm^2 is preferably used and a cell seeding density of 1.0×10^4 to 1.0×10^6 cells/cm^2 is more preferably used. When each microchamber is a square which is 200 μm on a side, for example, a cell seeding density of 5.0×10^4 to 5.0×10^5 cells/cm^2 is preferably used. Under such conditions, a mass of liver cells having a diameter of 30 to 200 μm can be obtained.

[0048]

Subsequently, an exemplary structure of the the cell culture kit according to this embodiment will be described referring to Figs. 7 to 10. Fig. 7 is a view showing an exemplary structure of the cell culture kit. A cell culture kit 30 includes a culture plate 32 with a flat shape. The culture plate 32 includes a plurality of culture dishes 34. A cell culture chamber 31 is arranged in each of the culture dishes 34. The number of the culture dishes 34 set in one culture plate 32 is determined depending on a method of screening, cell types to culture, or the number of cells to be used for a test. The culture plate 32 includes at least one cell culture chamber 31. The cell culture chamber 31 may have any one of three types of structures shown in Figs 1 to 6, for example. Other structures that satisfy the conditions of the concave-convex pattern described above may also be used. The bottom of the culture dish 34 has a flat plate shape, and the bottom surface of the cell culture chamber 31 is used as a culture surface.

[0049]

Figs. 8 to 10 show exemplary states in which living cells are cultured in a plurality of microchambers and differences among donors of seeded cells. In Figs. 8 to 10, each rectangle represents the microchamber 33. Figs. 8 and 9 show a case where the cell culture chamber 31 includes nine microchambers 33. Fig. 10 shows a case where the cell culture chamber 31 includes eighteen microchambers 33.

Further, references D1 to D3 represent cultured cells, and various patterns are used to show differences among donors of D1, D2, and D3.

[0050]

Fig. 8 shows a case where cells derived from one donor are adhered to each of the microchambers 33, and the donor of the cells in the one microchamber 33 is different from that of cells in adjacent microchambers 33. Fig. 9 shows a case where a mixture of living cells derived from various donors is adhered in some parts, and living cells derived from a single donor are adhered in other parts. This case shows an example where living cells derived from two donors are adhered to one microchamber 33. Fig. 10 shows a case where the plurality of microchambers 33 are divided into two divisions, and living cells of a first type donor are adhered to one division and living cells of a second type donor are adhered to the other division. Note that the plurality of microchambers 33 may be divided into three or more divisions. It is possible to confirm differences in testing result between various donors by adhering cells of a desired donor to each division.

[0051]

Though, Figs. 8 to 10 show exemplary arrangements of the living cells derived from various donors, the arrangement is not limited thereto. Other arrangements may also be employed as long as the living cells derived from various donors are adhered to and cultured in the plurality of microchambers 33 included in the cell culture kit 30. In particular, a plurality of living cells derived from various donors may be adhered to each of the microchambers 33. The number of types of donors of living cells to be adhered to one microchamber 33 may be three or more. Further, living cells derived from a single donor may be adhered to each of the microchambers 33, and the entire cell culture kit (or a single cell culture chamber 31) may contain living cells of a plurality of donors. More alternatively, living cells derived from a single donor are adhered to each one of the cell culture chambers 31, and living cells derived from various donors may be adhered to the plurality of cell culture chambers 31 as a whole. In other words, it is

sufficient that living cells derived from various donors are adhered to the cell culture kit 30.

[0052]

The living cells derived from various donors are cultured in the state of being adhered to the surface of each of the microchambers 33 of the cell culture kit 30. In the microchambers, the living cells are accumulated to form a cell mass. The cell mass is cultured up to a desired size. For example, the diameter of a cell mass to be cultured is 30 to 200 μm. The size of the microchamber is also determined depending on the size of the cell mass.

[0053]

Parenchymal cells derived from various donors are used as the living cells to be cultured in the microchambers. The parenchymal cells to be used are tissue precursor cells, tissue stem cells, cells differentiated from ES cells, parenchymal cells differentiated from iPS cells (induced pluripotent stem cells), or parenchymal cells derived from a living body.

[0054]

When various types of cell species are used, one type of parenchymal cells and other cell species are mixed and cultured. In this case, as for the derivation of cell species, parenchymal cells of various donors and other cell species derived from one donor, or parenchymal cells derived from one donor and other cell species derived from a donor different from the donor of the parenchymal cells may be used. As other cell species to be used, one or more cell species are selected from hepatic stellate cells, vascular endothelial cells, fibroblasts, and mesenchymal cells. Parenchymal cells, hepatic stellate cells, vascular endothelial cells, fibroblasts, and mesenchymal cells to be used are tissue precursor cells, tissue stem cells, cells differentiated from ES cells, cells differentiated from iPS cells (induced pluripotent stem cells), or cells derived from a living body.

[0055]

A culture medium to be used is a medium containing nutrient components, such as a nutrient factor, a blood serum, or a secretion

solution from cells. In the case of the secretion solution from cells, it is also possible to use a method of setting a chamber where cells are cultured on a membrane such as a cell culture insert.

[0056]

As described above, according to an aspect of the embodiment of the present invention, it is possible to provide a cell culture kit where living cells of various donors are adhered and cultured within a single chamber (within the cell culture kit). The cell culture kit includes a plurality of microchambers. As described above, the plurality of microchambers have a structure which allows the in vivo functions of the living cells to be maintained for a long term. Therefore, it is possible to provide living cells having in vivo-like cell functions. Additionally, it is possible to obtain testing results of various donors on a single chip. This makes it possible to efficiently carry out tests using cells derived from various donors over a long period of time.

[Examples]

[0057]

<Results of culturing various types of cells derived from various donors (such as parenchymal liver cells and non-parenchymal liver cells) in a plate including micro spaces>

1. Cell preparation

1-1.Culture of liver cells (Cell growth)

Transformed cells (hereinafter referred to as "transformed liver cells"), which were obtained by introducing a BMI1 gene into human hepatic stem cells (Accession Number FERM BP-11108, National Institute of Advanced Industrial Science and Technology, International Patent Organism Depositary), were seeded to a type-IV collagen coated dish (manufactured by Becton, Dickinson and Company) and cultured.

As a culture medium, a DMEM and nutrient mixture F-12 Ham medium (DMEM/F12 1:1 mixture) mixed with 10% fetal bovine serum (FBS), human γ-insulin (1.0 μg/ml), nicotinamide (10 mmol/l), dexamethasone (1×10^{-7} mol/l), and L-glutamine (2 mmol/l) was used. Culture was carried out in an incubator at 37°C and 5% CO_2, and the culture medium was changed every five days.

[0058]

1-2.Culture of vascular endothelial cells (Cell growth)

Human vascular endothelial cell lines derived from a donor different from the donor of the transformed liver cells were seeded a non-coated dish for cell culture (manufactured by Becton, Dickinson and Company) and cultured.

As a culture medium, a DMEM and nutrient mixture F-12 Ham medium (DMEM/F12 1:1 mixture) mixed with 10% fetal bovine serum (FBS), human γ-insulin (1.0 μg/ml), nicotinamide (10 mmol/l), dexamethasone (1×10^{-7} mol/l), and L-glutamine (2 mmol/l) was used. Culture was carried out in an incubator at 37°C and 5% CO_2, and the culture medium was changed every five days.

[0059]

1-3. Preparation of cell suspension

Each of the cells, which were cultured as described in the items 1-1 and 1-2, was detached using a 0.25% trypsin solution and collected, and was then dispersed into a culture medium.

As the culture medium, a DMEM and nutrient mixture F-12 Ham medium (DMEM/F12 1:1 mixture) mixed with 10% fetal bovine serum (FBS), human γ-insulin (1.0 μg/ml), nicotinamide (10 mmol/l), dexamethasone (1×10^{-7} mol/l), and L-glutamine (2 mmol/l) was used. Each of the cells was stained with trypan blue to count the number of living cells.

[0060]

2.Culture test (Example, Comparative Example)

2-1 <Example 01>

The transformed liver cells and vascular endothelial cells, which were obtained as described in the item 1-3, were mixed at a mixing ratio of 1:3, and were seeded in a culture chamber at a cell density of 3.75×10^{4} cells/cm^2. A 24-well type culture chamber which has the concave-convex pattern as shown in Figs. 3 and 4 and which includes micro spaces having dimensions of a=100 μm and c=50 μm was used as the culture chamber.

[0061]

2-2 <Comparative Example 01>

The transformed liver cells, which were obtained as described in the item 1-3, were seeded in a culture chamber at a cell density of 3.75×10^4 cells/cm^2. A 24-well type culture chamber which has the concave-convex pattern as shown in Figs. 3 and 4 and which includes micro spaces having dimensions of a=100 μm and c=50 μm was used as the culture chamber.

2-3 <Comparative Example 02>

The transformed liver cells, which were obtained as described in the item 1-3, were seeded in a 24-well cell culture plate (manufactured by Becton, Dickinson and Company) at a cell density of 3.75×10^4 cells/cm^2.

[0062]

2-4 Culturing method

After the cells were seeded as described in the items 2-1 and 2-2, the cells were cultured in an incubator at 37°C and 5% CO_2. After culturing for 24 hours, the culture medium was changed once a day or once every two days. As the culture medium, there was used a medium which was obtained adding a human recombinant HGF (50 ng/ml) and an epidermal growth factor (EGF) (10 ng/ml) to a DMEM and nutrient mixture F-12 Ham medium (DMEM/F12 1:1 mixture) mixed with 10% fetal bovine serum (FBS), human γ-insulin (1.0 μg/ml), nicotinamide (10 mmol/l), dexamethasone (1×10^{-7} mol/l), and L-glutamine (2 mmol/l).

[0063]

3. Gene expression analyses

Gene expressions of a cytochrome P450 (CYP), which is typical drug-metabolizing enzymes of a liver, and albumin were evaluated by carrying out real-time polymerase chain reaction after RNAs were collected from cells cultured for a given number of days to synthesize cDNAs.

[0064]

4. Experimental results (Results of gene expression analyses)

Table 1 shows gene expression levels of albumin, CYP3A4, and

CYP2C9 in Example 01 and Comparative Examples 01 and 02 after culturing for 21 days. In the table, relative values are shown as the gene expression levels assuming that the value of Example 02 is 1. In addition, the CYP3A4 and the CYP2C9 are examples of metabolic enzymes existing in the liver and each represent a molecular species name of a cytochrome P450 enzyme. CYPs play an important role of protecting living bodies from heterogeneities or foreign materials including various chemical agents (including drugs), environmental pollutants, and organic solvents.

Example 01 shows a significantly higher expression level than Comparative Examples 01 and 02 in any of the albumin, CYP3A3, and CYP2C9.

The experimental conditions, such as the number of cells and the mixing ratio, except for the case where different two types of cells are mixed and cultured, are not limited to the above-described conditions. Surface coating is not limited to the above, as long as cells can be adhered.

[0065]

[Table 1]

	Albumin	CYP3A4	CYP2C9
Example 01	105.1	458.0	51.8
Comparative Example 01	80.9	183.2	41.4
Comparative Example 02	1	1	1

[0066]

<Results of culture of liver cells derived from various donors in a plate including mirco spaces>

1. Cell seeding

In an example, human fetal liver cells obtained from six donor livers were used. Specifically, there were used the human fetal liver

cells derived from six donors, which include three types of cells: hepatic stem cells, liver precursor cells, and adult liver cells. In a comparative example, human fetal liver cells obtained from a single donor. In both the example and the comparative example, the cells were seeded in 24-well type culture chambers coated with a type-IV collagen and including micro spaces having dimensions of a=100 μm and c=50 μm as shown in Figs. 3 and 4 at a cell density of 3.75×10^4 cells/cm^2.

[0067]

2. Culture

Culture was carried out in an incubator at 37°C and 5% CO_2. After culturing for 24 hours, the culture medium was changed once a day or once every two days. As the culture medium, there was used a medium which was obtained adding a human recombinant HGF (50 ng/ml) and an epidermal growth factor (EGF) (10 ng/ml) to a DMEM and nutrient mixture F-12 Ham medium (DMEM/F12 1:1 mixture) mixed with 10% fetal bovine serum (FBS), human γ-insulin (1.0 μg/ml), nicotinamide (10 mmol/l), dexamethasone (1×10^{-7} mol/l), and L-glutamine (2 mmol/l).

[0068]

3. Analyses

3-1. Morphology observation

Observations were carried out using an inverted microscope on the 1st, 4th, 7th, 14th, 21st, and 35th day of culture.

3-2. Gene expressions of a cytochrome P450 (CYP) and albumin, and protein expression of CYP3A4

Gene expressions of a cytochrome P450 (CYP) which is typical drug-metabolizing enzymes of a liver and albumin were evaluated by carrying out real-time polymerase chain reaction after RNAs were collected from cells cultured for a given number of days to synthesize cDNAs. Protein expression was analyzed using an immunostaining procedure.

3-3. Glycogen storage capability

Differentiation capability (glycogen storage capability) in

human fetal liver cells was measured by PAS staining.

[0069]

4. Results

4-1. Results of morphology observation

Cells were adhered to the bottom surfaces of films at first, and was then gradually extended to other micro spaces (micro cavity) with the lapse of culture time and formed cell aggregates in the micro spaces. The morphology was similar to that of the comparative example described below. Accordingly, it turns out that cells of various donors can form an aggregate in the same manner as cells of one donor. Figs. 11A to 11F are photographs showing results of morphology observations of the example. Fig. 12 is a photograph showing a result of morphology observation on the 14th day of culture of the comparative example;

[0070]

4-2. Results of gene expressions of the cytochrome P450 (CYP) and the albumin, and the protein expression of CYP3A4

Primary drug-metabolizing enzymes CYP3A4, 2C19, 2C9, 1A2, and 2D6, and albumin secretory capability were measured. In the results, these CYP genes were expressed on the 7th day of culture, and the albumin and these CYP genes were expressed on the 21st day of culture. Even with the lapse of time, these functions were maintained. Fig. 13 is a photograph showing the measurement results. Fig. 13 shows the result obtained on the 7th day of culture on the left side, the result obtained on the 21st day of culture in the center, and the result obtained on the 35th day of culture on the right side.

In the immunostaining procedure, expressions of CYP3A4 (red) were confirmed in almost all the micro spaces (Fig. 14).
This stained image was similar to that of CYP3A4 of the comparative example described below (Fig. 15). Accordingly, it turns out that it is possible to culture cells of various donors while maintaining liver functions, in the same manner as cells of one donor.

[0071]

4-3. Results of glycogen storage capability

The differentiation capability (glycogen storage capability) in human fetal liver cells was studied. In the results, the glycogen storage capability was confirmed in the human fetal liver cells. Further, more than half of these cells were strongly PAS-positive on the 21st day of culture.

[0072]

The results of 4-1 to 4-3 show that it is possible to culture liver cells of various donors while maintaining liver functions in a state where liver cells of various donors are adhered to micro spaces.

[0073]

Note that the present invention is not limited to above-described embodiments. The elements of the embodiments can be modified, added, or converted to the contents that can be easily thought of by those skilled in the art within the scope of the present invention.

Reference Signs List

[0074]

10, 20	CELL CULTURE CHAMBER
11	MICROCHAMBER
12	SIDE WALL
13	OPENING
23	SPOT
24	SIDE WALL OF SPOT
30	CELL CULTURE KIT
31	CELL CULTURE CHAMBER
32	CULTURE PLATE
33	MICROCHAMBER
34	CULTURE DISH
D1, D2, D3	CELL

CLAIMS

1. A cell culture kit comprising:

a cell culture plate; and

living cells cultured on the culture plate;

wherein the culture plate includes a plurality of micro spaces, and living cells derived from various donors are adhered to surfaces of the plurality of micro spaces.

2. The cell culture kit according to Claim 1, wherein the living cells derived from various donors include two or more types of cells.

3. The cell culture kit according to Claim 1 or 2, wherein one of the living cells derived from various donors and living cells derived from a single donor are adhered to each of the plurality of micro spaces.

4. The cell culture kit according to Claim 1 or 2, wherein the living cells derived from various donors are adhered to at least two adjacent micro spaces.

5. The cell culture kit according to Claim 1 or 2, wherein living cells derived from a single donor are adhered to at least two adjacent micro spaces.

6. The cell culture kit according to any one of Claims 1 to 5, wherein the plurality of micro spaces have dimensions to allow a cell population of a three-dimensional structure to be isolated, the cell population being obtained by culture of a desired number of cells.

7. The cell culture kit according to any one of Claims 1 to 6, wherein the plurality of micro spaces have a bottom area of 0.01 to 0.1 mm^2 and a depth of 25 to 150 μm.

8. The cell culture kit according to any one of Claims 1 to 7, wherein the living cells are seeded in the plurality of micro spaces at a cell seeding density of 1×10^2 to 1×10^6 cells/cm^2.

9. The cell culture kit according to any one of Claims 1 to 8, wherein a cell mass having the living cells accumulated therein is formed in each of the plurality of micro spaces.

10. The cell culture kit according to any one of Claims 1 to 9, wherein the cell mass has a diameter of 30 to 200 μm.

11. The cell culture kit according to any one of Claims 1 to 10, wherein the living cells are one of tissue precursor cells, tissue stem cells, cells differentiated from ES cells, and cells differentiated from iPS cells.

12. The cell culture kit according to any one of Claims 1 to 10, wherein the living cells include liver cells.

13. The cell culture kit according to Claim 12, wherein the liver cells are one of tissue precursor cells, tissue stem cells, cells differentiated from ES cells, and cells differentiated from iPS cells.

14. The cell culture kit according to Claim 12, wherein the living cells including the liver cells are isolated from hepatic tissues of various donors.

15. A screening method for evaluating drugs by using a cell culture kit according to any one of Claims 1 to 14.

16. A method of manufacturing a cell culture kit which includes a culture plate including a plurality of micro spaces and living cells cultured thereon, the method comprising:

seeding living cells derived from various donors in the plurality

of micro spaces; and

culturing the seeded living cells.