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(54) Title: A MANUFACTURING FACILITY FOR THE PRODUCTION OF BIOPHARMACEUTICALS

(57) Abstract: A manufacturing facility for the continuous production of biopharmaceuticals integrated with single-use disposable technology.

## **A MANUFACTURING FACILITY FOR THE PRODUCTION OF BIOPHARMACEUTICALS**

### **CROSS REFERENCE TO RELATED APPLICATIONS**

**[0001]** This application claims priority to and the benefit of U.S. Provisional Application No. 62/246,478, filed October 26, 2015, and U.S. Provisional Application No. 62/299,930, filed February 25, 2016; the contents of both applications are incorporated herein by reference in their entireties.

### **BACKGROUND OF THE INVENTION**

**[0002]** Over the past few decades, the biopharmaceutical industry has made a number of advancements in developing more robust, efficient and cost effective methods for manufacturing biopharmaceuticals in batch mode. These advancements (e.g., expression systems, improved tools to develop and model production processes and adoption of single-use/disposable systems) can also be applied more acutely to current trends related to continuous bioprocesses. Continuous processing or production is a flow production method used to manufacture, produce, or process materials without interruption. Investments in continuous processing in the biopharmaceutical industry have been influenced by a number of business drivers, such as accelerated development times for continuously operated steps, reduced overall costs, maintained stringent quality, regulatory requirements, and increased flexibility to match changing product demands. Other advantages of continuous over batch production include consistent product quality, smaller equipment, streamlined process flow, low process cycle times, steady state operation, and high volumetric productivity.

**[0003]** In the biopharmaceutical industry, the term “single-use” (also commonly known as “disposable”) refers to a product that is intended for a one-time use. The adoption

of single-use technologies across all steps of biopharmaceutical manufacturing has accelerated in recent years. Today, users can choose from a large selection of single-use products from a range of suppliers. This trend is driven by a number of advantages over stainless steel systems reduced capital investment and operational costs, improved safety, and flexibility, etc., with respect to production scheduling. These advantages drive down contamination rates and enhance the efficiency of a production facility while reducing manufacturing costs (both operational and maintenance).

**[0004]** Single-use options exist for most steps of a protein bio-production process. Such options include process fluid mixing and storage systems, cryopreservation systems, bioreactors (used for both inoculum expansion and production process steps), bulk material and product storage, distribution assemblies and manifolds, sensors, and a number of disposable filtration and chromatography systems. Many of these technologies have already gained wide industry acceptance and furthermore, have been used to manufacture protein products that are approved by the regulatory authorities. For cell therapy manufacturing, plastic dishes and flasks have been used for adherent and non-adherent cell culture and a large proportion of adherent cell-based therapies are currently manufactured in multi-layered plastic flasks. The next generation of cell therapies will be manufactured using bioreactors. For this reason, bioreactor-based cell therapy manufacturing will benefit from utilizing single-use technologies at various, or even all, steps, including, but not limited to, tissue acquisition to final drug product formulation.

**[0005]** In this regard, the strategy is to increase the use of disposable technologies to produce high quality, safe, and cost effective active pharmaceutical ingredients (APIs) and biopharmaceutical products including, but not limited to, recombinant proteins, monoclonal antibodies, protein-drug conjugates, viral based therapeutics and cell therapies. With single-

use technologies, it is possible to maintain and increase quality, reliability of supply, throughput, and reduce costs of manufacturing processes. Moreover, the market shows an increase need to develop and implement disposable/single-use technologies for continuous bio-manufacturing operations or facilities. For example, contract manufacturing organizations often need to flexibly accommodate large-, mid- and small-volume drugs, preferably within the same manufacturing facilities.

### **SUMMARY OF THE INVENTION**

**[0006]** The present invention provides a manufacturing facility for the production of biopharmaceuticals that offers both batch and continuous manufacturing using at least one piece of single-use disposable technology.

**[0007]** The present invention also provides a manufacturing facility for the production of active pharmaceutical ingredients (“APIs”) that offers both batch and continuous manufacturing using at least one piece of single-use disposable technology.

**[0008]** In one aspect of the invention, the manufacturing facility may include at least one piece of single-use equipment or device configured to support continuous production of biopharmaceuticals.

**[0009]** In another aspect of the invention, the manufacturing facility may include at least one piece of single-use equipment or device configured to support continuous production of APIs.

**[0010]** In another aspect of the invention, the manufacturing facility may include at least one piece of single-use equipment or device configured to support continuous production cell therapy.

[0011] In another aspect of the invention, the manufacturing facility may include at least one piece of single-use equipment or device configured to support continuous production of bulk recombinant proteins and/or monoclonal antibody products.

[0012] Furthermore, for these contract manufacturing organizations, there are a number of factors that justify the implementation of single-use technologies. For instance, there would be greater flexibility in vessel architecture and components used when designing processes to manufacture proteins and cells, significantly reduced operating costs (e.g., labor, utility, and maintenance), improved facility throughput as batch turnaround times are condensed, clean in place and steam in place operations.

[0013] Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of one or more preferred embodiments when considered in conjunction with the accompanying drawings. The disclosure is written for those skilled in the art. Although the disclosure uses terminology and acronyms that may not be familiar to the layperson, those skilled in the art will be familiar with the terminology and acronyms used herein.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

[0014] Figure 1 is a schematic representation of batch process options with example technologies. In Figure 1, “o” represents a connector and “-” represents a tube.

[0015] Figure 2 is a schematic representation of continuous process options with example technologies. In Figure 2, “o” represents a connector and “-” represents a tube.

[0016] Figure 3 is a schematic representation of hybrid process options with example technologies. In Figure 3, “o” represents a connector and “-” represents a tube.

[0017] Figure 4 shows antibody concentration profiles for a Model GS-CHO Cell Line in laboratory-scale bioreactors with a comparison between the Version 6, Version 7 and Version 8 platform processes. Figure 4 insert: Top 3 cell lines selected and evaluated from a single cell line construction.

[0018] Figure 5 is a schematic representation of continuous, batch and hybrid process options with example technologies.

[0019] Figure 6 shows the implementation of single-use equipment in mammalian cell-culture manufacturing facilities in accordance with one or more aspects of the invention.

#### **DETAILED DESCRIPTION**

[0020] The present invention takes advantage of new and converging single-use technologies and integrates those technologies into a batch-fed, continuous, and/or hybrid manufacturing facilities and processes. The present invention provides improved methods, associated apparatus, and systems for manufacturing biopharmaceuticals. Provided herein are systems, facilities, means, and processes to address batch-fed, continuous, and hybrid manufacturing in a reasonable time with high yield and product quality. Also provided herein are systems, facilities, means, and processes to optimize production while reducing the risk of contamination. The disclosed methods and systems provide optimized configurations, partly or completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of cell production, including: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for the capture step (5), ultrafiltration and diafiltration equipment (6), polishing membranes (7), equipment for polishing using cation exchange (8), virus reduction filtration equipment (9), ultrafiltration and diafiltration

equipment (10), and automated bulk fill equipment (11). The disclosed methods and systems also provide optimized configurations, partly or completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of cell production, including: input cells (1), inoculum expansion equipment (2), production stage perfusion equipment (12), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11). In addition, the disclosed methods and systems also provide optimized configurations, partly or completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of cell production, including: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0021] The present invention provides embodiments that involve a direct connection between input cells (1) and inoculum expansion equipment (2). This direct connection may also have a sensor that would allow the manufacturing process to be continuous only regarding this transfer. This would eliminate the need for a processing step involving shake flask incubation.

[0022] Moreover, the present invention provides for sensors to monitor any process variable, including, but not limited to, protein concentration, pH, conductivity, viable cell concentration, capacitance, key metabolites, temperature, titer, metabolites, glucose reuptake, DO, CO<sub>2</sub> generation, O<sub>2</sub> reuptake rate, HPLC, organic acids, saccharides, TCA intermediates, vitamins, nucleotides, elements, endotoxins, bioburdens, etc. These sensors optionally can be

in communication with other sensors, and can also optionally adjust the flow rate of fluid into and/or out of at least one piece of equipment. These sensors can also be in-line sensors or at-line sensors. These sensors or their equivalents are able to communicate with the equipment, each other, a computer, the internet, or the like. Communication between sensors can be done in many ways. As just one illustrative example, communication can be accomplished using the invention as described in U.S. Patent Application No. 15/294,152, filed on October 14, 2016. These sensors have the advantage of reducing human error in manufacturing.

**[0023]** Also, the present invention can be automated. For example, sensors could be used to determine seed transfer, harvest initiation, timing for process shifts, feed control, feed timing, feed flow rates, inline buffer dilution, chromatography peak cutting, VI titration, UF/DF completion, release tanks/skids, real time modification of chromatography recipes, and the like.

**[0024]** The present invention also provides for different pieces of manufacturing equipment, including hoses and/or connectors, to be surrounded by disposable bags such that the bags may be used to dispose of any one or more pieces of single-use items. The present invention additionally provides that one or more pieces of equipment can be in separate rooms and be connected to equipment in other rooms. Additionally, pieces that are in separate rooms may not be directly connected to those in another room but still be used as part of the present invention. Furthermore, not all of the equipment needs to be single-use equipment.

**[0025]** The present invention provides a methodology for selecting the optimal equipment for use in this invention. For example, factors to consider when selecting the equipment for process recovery includes: pressure, flux, pH, turbidity, acidification, capacity,

cost, minimum filter area, filtration rate, de-sludge interval, efficiency, percentage of solids, storage, etc. The present invention also provides criteria for selecting bioreactors, including: mass transfer of O<sub>2</sub>, cell growth, culture viability, lactate concentration, ammonium concentration, sodium concentration, potassium concentration, partial pressure of CO<sub>2</sub>, glutamine concentration, osmolality, antibody concentration, temperature, oligosaccharides, the presence or absence of baffles, etc. Likewise, the present invention provides criteria for selecting equipment for continuous chromatography, such as multi-column systems, including: the interconnection of columns for an optimal use of the resin, ability to be automated or semi-automated, number of columns that can be used, amount of raw material, manufacturing time, product quality, time to process, ability to reach steady state, number of inlets, buffer consumption, higher yields at purification steps, ability to operate in batch and continuous modes depending on need, etc.

[0026] Figure 5 discloses exemplary equipment that could be used to make and use the inventions described herein. For example, the equipment for input cells (1) can be any suitable cell culture equipment including a cell culture flask, such as those commercially available from Corning Inc., that for inoculum expansion equipment (2) can be any suitable expansion equipment such as an S20 WAVE unit commercially available from General Electric Company, the production stage bioreactor equipment (3) could be any suitable bioreactor such as a BIOSTAT<sup>®</sup> system commercially available from Sartorius AG, the primary recovery stage equipment (4) could be any suitable filter recovery system such as a Zeta Plus<sup>™</sup> recovery system commercially available from 3M, the equipment for the capture step (5) could be any suitable chromatography column such as an RTP column commercially available from General Electric Company, the ultrafiltration and diafiltration equipment (6) and (10) could be any suitable ultrafiltration and diafiltration unit such as the Hydrosart<sup>®</sup>

commercially available from Sartorius AG, the polishing membranes (7) could be any suitable membranes such as those that are commercially available from Sartorius AG, the equipment for polishing using cation exchange (8) could be any suitable chromatography column such as an RTP column commercially available from General Electric Company, the virus reduction filtration equipment (9) could be any suitable virus reduction system such as the Planova™ 20N commercially available from Asahi Kasei Medical Co., Ltd., the automated bulk fill equipment (11) could be any suitable fill equipment such as the SciLog® SciFlex® Filter and Dispense System commercially available from Parker Domnick Hunter, the production stage perfusion equipment (12) could be any suitable production stage perfusion reactor equipment such as the Allegro STR bioreactor family commercially available from Pall Corporation and/or the XCell™ ATF system commercially available from Repligen Corporation, the equipment for volume exchange (13) could be any suitable volume exchange equipment such as the ILC system commercially available from Pall Corporation, and the continuous purification equipment (14) could be any suitable purification equipment such as the BioSMB system commercially available from Pall Corporation.

[0027] In addition, it is an object of the present invention that these Batch-fed, continuous, and/or hybrid manufacturing facilities and processes can be done in one or more facilities. For example, one or more steps could be done in one or more separate facilities from the others. It is an object of the present invention that these processes can comply with state, federal, and international regulations regarding Good Manufacturing Processes.

[0028] Batch-fed, continuous, and/or hybrid manufacturing facilities and processes each have their advantages and disadvantages that depend on numerous factors such as, but not limited to, cost, cell-type, output volume requirements, and the like. Therefore, it is an object of the present invention to be able to switch between any of these processes and

facilities. Such modifications could be quick, timely and/or inexpensive. Such modifications could be done in such a way as to minimize the risk of contamination by, for example, inadvertent dripping on the manufacturing floor from any of the tubes, connectors, machines, or the like. For example, at least one tube between manufacturing components could include a single use tube. Likewise, at least one connector that connects a tube to a piece of manufacturing equipment could be a single use connector. As well, more than one of these connecting tubes and/or connectors could be a single-use item.

**[0029]** It is another object of the present invention to use at least one piece of single-use manufacturing equipment in the manufacturing facilities and processes of the present invention.

**[0030]** It is another object of the present invention to use at least one piece of single-use connection equipment in the manufacturing facilities and processes of the present invention.

**[0031]** The goal is to move towards a continuous process option in which the product moves directly from one step to the next without any significant intervening product hold (*see* e.g., Figures 1, 2, and 3).

**[0032]** Preferably, the continuous process would operate at a true steady-state, with the operating conditions (e.g., flow rates and pressures) and product/impurity concentrations remaining constant throughout the process. With this, fully integrated, continuous single-use bioprocessing would allow for predictable steady manufacture at smaller scales (therefore requiring smaller equipment and reducing footprint in existing plants and minimizes the size of new plants) with the associated cost savings and benefits. This fully integrated system could also be operated on a larger scale, if such were needed.

**[0033]** The devices, facilities and methods described herein are suitable for culturing any desired cell line including prokaryotic and/or eukaryotic cell lines. Further, in embodiments, the devices, facilities and methods are suitable for culturing suspension cells or anchorage-dependent (adherent) cells and are suitable for production operations configured for production of pharmaceutical and biopharmaceutical products—such as polypeptide products, nucleic acid products (for example DNA or RNA), or cells and/or viruses such as those used in cellular and/or viral therapies.

**[0034]** In embodiments, the cells express or produce a product, such as a recombinant therapeutic or diagnostic product. As described in more detail below, examples of products produced by cells include, but are not limited to, antibody molecules (e.g., monoclonal antibodies, bispecific antibodies), antibody mimetics (polypeptide molecules that bind specifically to antigens but that are not structurally related to antibodies such as e.g. DARPins, affibodies, adnectins, or IgNARs), fusion proteins (e.g., Fc fusion proteins, chimeric cytokines), other recombinant proteins (e.g., glycosylated proteins, enzymes, hormones), viral therapeutics (e.g., anti-cancer oncolytic viruses, viral vectors for gene therapy and viral immunotherapy), cell therapeutics (e.g., pluripotent stem cells, mesenchymal stem cells and adult stem cells), vaccines or lipid-encapsulated particles (e.g., exosomes, virus-like particles), RNA (such as e.g. siRNA) or DNA (such as e.g. plasmid DNA), antibiotics or amino acids. In embodiments, the devices, facilities and methods can be used for producing biosimilars.

**[0035]** As mentioned, in embodiments, devices, facilities and methods allow for the production of eukaryotic cells, e.g., mammalian cells or lower eukaryotic cells such as for example yeast cells or filamentous fungi cells, or prokaryotic cells such as Gram-positive or Gram-negative cells and/or products of the eukaryotic or prokaryotic cells, e.g., proteins,

peptides, antibiotics, amino acids, nucleic acids (such as DNA or RNA), synthesized by the eukaryotic cells in a large-scale manner. Unless stated otherwise herein, the devices, facilities, and methods can include any desired volume or production capacity including but not limited to bench-scale, pilot-scale, and full production scale capacities.

**[0036]** Moreover and unless stated otherwise herein, the devices, facilities, and methods can include any suitable reactor(s) including but not limited to stirred tank, airlift, fiber, microfiber, hollow fiber, ceramic matrix, fluidized bed, fixed bed, single-use and/or spouted bed bioreactors. As used herein, “reactor” can include a fermentor or fermentation unit, or any other reaction vessel and the term “reactor” is used interchangeably with “fermentor.” For example, in some aspects, an example bioreactor unit can perform one or more, or all, of the following: feeding of nutrients and/or carbon sources, injection of suitable gas (e.g., oxygen), inlet and outlet flow of fermentation or cell culture medium, separation of gas and liquid phases, maintenance of temperature, maintenance of oxygen and CO<sub>2</sub> levels, maintenance of pH level, agitation (e.g., stirring), and/or cleaning/sterilizing. Example reactor units, such as a fermentation unit, may contain multiple reactors within the unit, for example the unit can have 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, or 100, or more bioreactors in each unit and/or a facility may contain multiple units having a single or multiple reactors within the facility. In various embodiments, the bioreactor can be suitable for batch, semi fed-batch, fed-batch, perfusion, and/or a continuous fermentation processes. Any suitable reactor diameter can be used. In embodiments, the bioreactor can have a volume between about 100 mL and about 50,000 L. Non-limiting examples include a volume of 100 mL, 250 mL, 500 mL, 750 mL, 1 liter, 2 liters, 3 liters, 4 liters, 5 liters, 6 liters, 7 liters, 8 liters, 9 liters, 10 liters, 15 liters, 20 liters, 25 liters, 30 liters, 40 liters, 50 liters, 60 liters, 70 liters, 80 liters, 90 liters, 100 liters, 150 liters, 200 liters, 250 liters, 300 liters, 350 liters, 400

liters, 450 liters, 500 liters, 550 liters, 600 liters, 650 liters, 700 liters, 750 liters, 800 liters, 850 liters, 900 liters, 950 liters, 1000 liters, 1500 liters, 2000 liters, 2500 liters, 3000 liters, 3500 liters, 4000 liters, 4500 liters, 5000 liters, 6000 liters, 7000 liters, 8000 liters, 9000 liters, 10,000 liters, 15,000 liters, 20,000 liters, and/or 50,000 liters. Additionally, suitable reactors can be multi-use, single-use, disposable, or non-disposable and can be formed of any suitable material including metal alloys such as stainless steel (e.g., 316L or any other suitable stainless steel) and Inconel, plastics, and/or glass.

**[0037]** In embodiments and unless stated otherwise herein, the devices, facilities, and methods described herein can also include any suitable unit operation and/or equipment not otherwise mentioned, such as operations and/or equipment for separation, purification, and isolation of such products. Any suitable facility and environment can be used, such as traditional stick-built facilities, modular, mobile and temporary facilities, or any other suitable construction, facility, and/or layout. For example, in some embodiments modular clean-rooms can be used. Additionally and unless otherwise stated, the devices, systems, and methods described herein can be housed and/or performed in a single location or facility or alternatively be housed and/or performed at separate or multiple locations and/or facilities.

**[0038]** By way of non-limiting examples and without limitation, U.S. Publication Nos. 2013/0280797, 2012/0077429, 2011/0280797, 2009/0305626, and U.S. Patent Nos. 8,298,054, 7,629,167, and 5,656,491, each of which are hereby incorporated by reference in its entirety, describe example facilities, equipment, and/or systems that may be suitable.

**[0039]** In embodiments, the cells are eukaryotic cells, e.g., mammalian cells. The mammalian cells can be for example human or rodent or bovine cell lines or cell strains. Examples of such cells, cell lines or cell strains are e.g., mouse myeloma (NSO)-cell lines,

Chinese hamster ovary (CHO)-cell lines, HT1080, H9, HepG2, MCF7, MDBK Jurkat, NIH3T3, PC12, BHK (baby hamster kidney cell), VERO, SP2/0, YB2/0, Y0, C127, L cell, COS, e.g., COS1 and COS7, QC1-3, HEK-293, VERO, PER.C6, HeLA, EB1, EB2, EB3, oncolytic or hybridoma-cell lines. Preferably the mammalian cells are CHO-cell lines. In one embodiment, the cell is a CHO cell. In one embodiment, the cell is a CHO-K1 cell, a CHO-K1 SV cell, a DG44 CHO cell, a DUXB11 CHO cell, a CHOS, a CHO GS knock-out cell, a CHO FUT8 GS knock-out cell, a CHOZN, or a CHO-derived cell. The CHO GS knock-out cell (e.g., GSKO cell) is, for example, a CHO-K1 SV GS knockout cell. The CHO FUT8 knockout cell is, for example, the Potelligent® CHOK1 SV (Lonza Biologics, Inc.). Eukaryotic cells can also be avian cells, cell lines or cell strains, such as for example, EBx® cells, EB14, EB24, EB26, EB66, or EBv13.

**[0040]** In one embodiment, the eukaryotic cells are stem cells. The stem cells can be, for example, pluripotent stem cells, including embryonic stem cells (ESCs), adult stem cells, induced pluripotent stem cells (iPSCs), tissue specific stem cells (e.g., hematopoietic stem cells) and mesenchymal stem cells (MSCs).

**[0041]** In one embodiment, the cell is a differentiated form of any of the cells described herein. In one embodiment, the cell is a cell derived from any primary cell in culture.

**[0042]** In embodiments, the cell is a hepatocyte such as a human hepatocyte, animal hepatocyte, or a non-parenchymal cell. For example, the cell can be a plateable metabolism qualified human hepatocyte, a plateable induction qualified human hepatocyte, plateable Qualyst Transporter Certified™ human hepatocyte, suspension qualified human hepatocyte (including 10-donor and 20-donor pooled hepatocytes), human hepatic kupffer cells, human

hepatic stellate cells, dog hepatocytes (including single and pooled Beagle hepatocytes), mouse hepatocytes (including CD-1 and C57BI/6 hepatocytes), rat hepatocytes (including Sprague-Dawley, Wistar Han, and Wistar hepatocytes), monkey hepatocytes (including Cynomolgus or Rhesus monkey hepatocytes), cat hepatocytes (including Domestic Shorthair hepatocytes), and rabbit hepatocytes (including New Zealand White hepatocytes). Example hepatocytes are commercially available from Triangle Research Labs, LLC, 6 Davis Drive Research Triangle Park, North Carolina, USA 27709.

**[0043]** In one embodiment, the eukaryotic cell is a lower eukaryotic cell such as e.g., a yeast cell (e.g., *Pichia* genus (e.g., *Pichia pastoris*, *Pichia methanolica*, *Pichia kluyveri*, and *Pichia angusta*), *Komagataella* genus (e.g., *Komagataella pastoris*, *Komagataella pseudopastoris* or *Komagataella phaffii*), *Saccharomyces* genus (e.g., *Saccharomyces cerevisiae*, *cerevisiae*, *Saccharomyces kluyveri*, *Saccharomyces uvarum*), *Kluyveromyces* genus (e.g., *Kluyveromyces lactis*, *Kluyveromyces marxianus*), the *Candida* genus (e.g., *Candida utilis*, *Candida cacaoi*, *Candida boidinii*), the *Geotrichum* genus (e.g., *Geotrichum fermentans*), *Hansenula polymorpha*, *Yarrowia lipolytica*, or *Schizosaccharomyces pombe*. Preferred is the species *Pichia pastoris*. Examples for *Pichia pastoris* strains are X33, GS115, KM71, KM71H; and CBS7435.

**[0044]** In one embodiment, the eukaryotic cell is a fungal cell (e.g., *Aspergillus* (such as *A. niger*, *A. fumigatus*, *A. oryzae*, *A. nidula*), *Acremonium* (such as *A. thermophilum*), *Chaetomium* (such as *C. thermophilum*), *Chrysosporium* (such as *C. thermophile*), *Cordyceps* (such as *C. militaris*), *Corynascus*, *Ctenomyces*, *Fusarium* (such as *F. oxysporum*), *Glomerella* (such as *G. graminicola*), *Hypocrea* (such as *H. jecorina*), *Magnaporthe* (such as *M. oryzae*), *Myceliophthora* (such as *M. thermophile*), *Nectria* (such as *N. heamatococca*), *Neurospora* (such as *N. crassa*), *Penicillium*, *Sporotrichum* (such as *S. thermophile*),

Thielavia (such as *T. terrestris*, *T. heterothallica*), Trichoderma (such as *T. reesei*), or Verticillium (such as *V. dahlia*)).

[0045] In one embodiment, the eukaryotic cell is an insect cell (e.g., Sf9, Mimic™ Sf9, Sf21, High Five™ (BT1-TN-5B1-4), or BT1-Ea88 cells), an algae cell (e.g., of the genus Amphora, Bacillariophyceae, Dunaliella, Chlorella, Chlamydomonas, Cyanophyta (cyanobacteria), Nannochloropsis, Spirulina, or Ochromonas), or a plant cell (e.g., cells from monocotyledonous plants (e.g., maize, rice, wheat, or Setaria), or from a dicotyledonous plants (e.g., cassava, potato, soybean, tomato, tobacco, alfalfa, *Physcomitrella patens* or Arabidopsis).

[0046] In one embodiment, the cell is a bacterial or prokaryotic cell.

[0047] In embodiments, the prokaryotic cell is a Gram-positive cells such as Bacillus, Streptomyces Streptococcus, Staphylococcus or Lactobacillus. Bacillus that can be used is, e.g. the *B.subtilis*, *B.amyloliquefaciens*, *B.licheniformis*, *B.natto*, or *B.megaterium*. In embodiments, the cell is *B.subtilis*, such as *B.subtilis 3NA* and *B.subtilis 168*. Bacillus is obtainable from, e.g., the Bacillus Genetic Stock Center, Biological Sciences 556, 484 West 12<sup>th</sup> Avenue, Columbus OH 43210-1214.

[0048] In one embodiment, the prokaryotic cell is a Gram-negative cell, such as Salmonella spp. or Escherichia coli, such as e.g., TG1, TG2, W3110, DH1, DHB4, DH5a, HMS 174, HMS174 (DE3), NM533, C600, HB101, JM109, MC4100, XL1-Blue and Origami, as well as those derived from E.coli B-strains, such as for example BL-21 or BL21 (DE3), all of which are commercially available.

[0049] Suitable host cells are commercially available, for example, from culture collections such as the DSMZ (Deutsche Sammlung von Mikroorganismen and Zellkulturen GmbH, Braunschweig, Germany) or the American Type Culture Collection (ATCC).

[0050] In embodiments, the cultured cells are used to produce proteins e.g., antibodies, e.g., monoclonal antibodies, and/or recombinant proteins, for therapeutic use. In embodiments, the cultured cells produce peptides, amino acids, fatty acids or other useful biochemical intermediates or metabolites. For example, in embodiments, molecules having a molecular weight of about 4000 daltons to greater than about 140,000 daltons can be produced. In embodiments, these molecules can have a range of complexity and can include posttranslational modifications including glycosylation.

[0051] In embodiments, the protein is, e.g., BOTOX, Myobloc, Neurobloc, Dysport (or other serotypes of botulinum neurotoxins), alglucosidase alpha, daptomycin, YH-16, choriogonadotropin alpha, filgrastim, cetorelix, interleukin-2, aldesleukin, teceleulin, denileukin diftitox, interferon alpha-n3 (injection), interferon alpha-n1, DL-8234, interferon, Suntory (gamma-1a), interferon gamma, thymosin alpha 1, tasonermin, DigiFab, ViperaTAb, EchiTAb, CroFab, nesiritide, abatacept, alefacept, Rebif, eptoterminalfa, teriparatide (osteoporosis), calcitonin injectable (bone disease), calcitonin (nasal, osteoporosis), etanercept, hemoglobin glutamer 250 (bovine), drotrecogin alpha, collagenase, carperitide, recombinant human epidermal growth factor (topical gel, wound healing), DWP401, darbepoetin alpha, epoetin omega, epoetin beta, epoetin alpha, desirudin, lepirudin, bivalirudin, nonacog alpha, Mononine, eptacog alpha (activated), recombinant Factor VIII+VWF, Recombinate, recombinant Factor VIII, Factor VIII (recombinant), Alphanmate, octocog alpha, Factor VIII, palifermin, Indikinase, tenecteplase, alteplase, pamiteplase, reteplase, nateplase, monteplase, follitropin alpha, rFSH, hpFSH, micafungin, pegfilgrastim,

lenograstim, nartograstim, sermorelin, glucagon, exenatide, pramlintide, iniglucerase, galsulfase, Leucotropin, molgramostirn, triptorelin acetate, histrelin (subcutaneous implant, Hydron), deslorelin, histrelin, nafarelin, leuprolide sustained release depot (ATRIGEL), leuprolide implant (DUROS), goserelin, Eutropin, KP-102 program, somatropin, mecasermin (growth failure), enfavirtide, Org-33408, insulin glargine, insulin glulisine, insulin (inhaled), insulin lispro, insulin deternir, insulin (buccal, RapidMist), mecasermin rinfabate, anakinra, celmoleukin, 99 mTc-apcitide injection, myelopid, Betaseron, glatiramer acetate, Gepon, sargramostim, oprelvekin, human leukocyte-derived alpha interferons, Bilive, insulin (recombinant), recombinant human insulin, insulin aspart, mecasermin, Roferon-A, interferon-alpha 2, Alfaferone, interferon alfacon-1, interferon alpha, Avonex' recombinant human luteinizing hormone, dornase alpha, trafermin, ziconotide, taltirelin, diboterminalfa, atosiban, becaplermin, eptifibatide, Zemaira, CTC-111, Shanvac-B, HPV vaccine (quadrivalent), octreotide, lanreotide, ancestirn, agalsidase beta, agalsidase alpha, laronidase, prezatide copper acetate (topical gel), rasburicase, ranibizumab, Actimmune, PEG-Intron, Tricommin, recombinant house dust mite allergy desensitization injection, recombinant human parathyroid hormone (PTH) 1-84 (sc, osteoporosis), epoetin delta, transgenic antithrombin III, Granditropin, Vitrase, recombinant insulin, interferon-alpha (oral lozenge), GEM-21S, vapreotide, idursulfase, omnapatrilat, recombinant serum albumin, certolizumab pegol, glucarpidase, human recombinant C1 esterase inhibitor (angioedema), lanotepase, recombinant human growth hormone, enfuvirtide (needle-free injection, Biojector 2000), VGV-1, interferon (alpha), lucinactant, aviptadil (inhaled, pulmonary disease), icatibant, ecallantide, omiganan, Aurograb, pexigananacetate, ADI-PEG-20, LDI-200, degarelix, cintredelinbesudotox, Favld, MDX-1379, ISAtx-247, liraglutide, teriparatide (osteoporosis), tifacogin, AA4500, T4N5 liposome lotion, catumaxomab, DWP413, ART-123, Chrysalin,

desmotepase, amediplase, corifollitropinalpha, TH-9507, teduglutide, Diamyd, DWP-412, growth hormone (sustained release injection), recombinant G-CSF, insulin (inhaled, AIR), insulin (inhaled, Technosphere), insulin (inhaled, AERx), RGN-303, DiaPep277, interferon beta (hepatitis C viral infection (HCV)), interferon alpha-n3 (oral), belatacept, transdermal insulin patches, AMG-531, MBP-8298, Xerecept, opebacan, AIDS VAX, GV-1001, LymphoScan, ranpirnase, Lipoxysan, lusupultide, MP52 (beta-tricalciumphosphate carrier, bone regeneration), melanoma vaccine, sipuleucel-T, CTP-37, Insegia, vitespen, human thrombin (frozen, surgical bleeding), thrombin, TransMID, alfimeprase, Puricase, terlipressin (intravenous, hepatorenal syndrome), EUR-1008M, recombinant FGF-I (injectable, vascular disease), BDM-E, rotigaptide, ETC-216, P-113, MBI-594AN, duramycin (inhaled, cystic fibrosis), SCV-07, OPI-45, Endostatin, Angiostatin, ABT-510, Bowman Birk Inhibitor Concentrate, XMP-629, 99 mTc-Hynic-Annexin V, kahalalide F, CTCE-9908, teverelix (extended release), ozarelix, romidepsin, BAY-504798, interleukin4, PRX-321, Pepscan, iboctadekin, rh lactoferrin, TRU-015, IL-21, ATN-161, cilengitide, Albuferon, Biphaxis, IRX-2, omega interferon, PCK-3145, CAP-232, pasireotide, huN901-DMI, ovarian cancer immunotherapeutic vaccine, SB-249553, Oncovax-CL, OncoVax-P, BLP-25, CerVax-16, multi-epitope peptide melanoma vaccine (MART-1, gp100, tyrosinase), nemifitide, rAAT (inhaled), rAAT (dermatological), CGRP (inhaled, asthma), pegsunercept, thymosinbeta4, plitidepsin, GTP-200, ramoplanin, GRASPA, OBI-1, AC-100, salmon calcitonin (oral, eligen), calcitonin (oral, osteoporosis), examorelin, capromorelin, Cardeva, velafermin, 131I-TM-601, KK-220, T-10, ularitide, depelestat, hematide, Chrysalin (topical), rNAPc2, recombinant Factor V111 (PEGylated liposomal), bFGF, PEGylated recombinant staphylokinase variant, V-10153, SonoLysis Prolyse, NeuroVax, CZEN-002, islet cell neogenesis therapy, rGLP-1, BIM-51077, LY-548806, exenatide (controlled release,

Medisorb), AVE-0010, GA-GCB, avorelin, ACM-9604, linaclotid acetate, CETi-1, Hemospan, VAL (injectable), fast-acting insulin (injectable, Viadel), intranasal insulin, insulin (inhaled), insulin (oral, eligen), recombinant methionyl human leptin, pitrakinra subcutaneous injection, eczema), pitrakinra (inhaled dry powder, asthma), Multikine, RG-1068, MM-093, NBI-6024, AT-001, PI-0824, Org-39141, Cpn10 (autoimmune diseases/inflammation), talactoferrin (topical), rEV-131 (ophthalmic), rEV-131 (respiratory disease), oral recombinant human insulin (diabetes), RPI-78M, oprelvekin (oral), CYT-99007 CTLA4-Ig, DTY-001, valategrast, interferon alpha-n3 (topical), IRX-3, RDP-58, Tauferon, bile salt stimulated lipase, Merispase, alkaline phosphatase, EP-2104R, Melanotan-II, bremelanotide, ATL-104, recombinant human microplasmin, AX-200, SEMAX, ACV-1, Xen-2174, CJC-1008, dynorphin A, SI-6603, LAB GHRH, AER-002, BGC-728, malaria vaccine (viroosomes, PeviPRO), ALTU-135, parvovirus B19 vaccine, influenza vaccine (recombinant neuraminidase), malaria/HBV vaccine, anthrax vaccine, Vacc-5q, Vacc-4x, HIV vaccine (oral), HPV vaccine, Tat Toxoid, YPSL, CHS-13340, PTH(1-34) liposomal cream (Novasome), Ostabolin-C, PTH analog (topical, psoriasis), MBRI-93.02, MTB72F vaccine (tuberculosis), MVA-Ag85A vaccine (tuberculosis), FARA04, BA-210, recombinant plague FIV vaccine, AG-702, OxSODrol, rBetV1, Der-p1/Der-p2/Der-p7 allergen-targeting vaccine (dust mite allergy), PR1 peptide antigen (leukemia), mutant ras vaccine, HPV-16 E7 lipopeptide vaccine, labyrinthin vaccine (adenocarcinoma), CML vaccine, WT1-peptide vaccine (cancer), IDD-5, CDX-110, Pentrys, Norelin, CytoFab, P-9808, VT-111, icrocaptide, telbermin (dermatological, diabetic foot ulcer), rupintrivir, reticulose, rGRF, HA, alpha-galactosidase A, ACE-011, ALTU-140, CGX-1160, angiotensin therapeutic vaccine, D-4F, ETC-642, APP-018, rhMBL, SCV-07 (oral, tuberculosis), DRF-7295, ABT-828, ErbB2-specific immunotoxin (anticancer), DT3SSIL-3, TST-10088, PRO-1762, Combotox,

cholecystokinin-B/gastrin-receptor binding peptides, 111In-hEGF, AE-37, trasnizumab-DM1, Antagonist G, IL-12 (recombinant), PM-02734, IMP-321, rhIGF-BP3, BLX-883, CUV-1647 (topical), L-19 based radioimmunotherapeutics (cancer), Re-188-P-2045, AMG-386, DC/1540/KLH vaccine (cancer), VX-001, AVE-9633, AC-9301, NY-ESO-1 vaccine (peptides), NA17.A2 peptides, melanoma vaccine (pulsed antigen therapeutic), prostate cancer vaccine, CBP-501, recombinant human lactoferrin (dry eye), FX-06, AP-214, WAP-8294A (injectable), ACP-HIP, SUN-11031, peptide YY [3-36] (obesity, intranasal), FGLL, atacicept, BR3-Fc, BN-003, BA-058, human parathyroid hormone 1-34 (nasal, osteoporosis), F-18-CCR1, AT-1100 (celiac disease/diabetes), JPD-003, PTH(7-34) liposomal cream (Novasome), duramycin (ophthalmic, dry eye), CAB-2, CTCE-0214, GlycoPEGylated erythropoietin, EPO-Fc, CNTO-528, AMG-114, JR-013, Factor XIII, aminocandin, PN-951, 716155, SUN-E7001, TH-0318, BAY-73-7977, teverelix (immediate release), EP-51216, hGH (controlled release, Biosphere), OGP-I, sifuvirtide, TV4710, ALG-889, Org-41259, rhCC10, F-991, thymopentin (pulmonary diseases), r(m)CRP, hepatoselective insulin, subalin, L19-IL-2 fusion protein, elafin, NMK-150, ALTU-139, EN-122004, rhTPO, thrombopoietin receptor agonist (thrombocytopenic disorders), AL-108, AL-208, nerve growth factor antagonists (pain), SLV-317, CGX-1007, INNO-105, oral teriparatide (eligen), GEM-OS1, AC-162352, PRX-302, LFn-p24 fusion vaccine (Therapore), EP-1043, S pneumoniae pediatric vaccine, malaria vaccine, Neisseria meningitidis Group B vaccine, neonatal group B streptococcal vaccine, anthrax vaccine, HCV vaccine (gpE1+gpE2+MF-59), otitis media therapy, HCV vaccine (core antigen+ISCOMATRIX), hPTH(1-34) (transdermal, ViaDerm), 768974, SYN-101, PGN-0052, aviscumnine, BIM-23190, tuberculosis vaccine, multi-epitope tyrosinase peptide, cancer vaccine, enkastim, APC-8024,

GI-5005, ACC-001, TTS-CD3, vascular-targeted TNF (solid tumors), desmopressin (buccal controlled-release), onercept, and TP-9201.

[0052] In some embodiments, the polypeptide is adalimumab (HUMIRA), infliximab (REMICADE™), rituximab (RITUXAN™/MAB THERA™) etanercept (ENBREL™), bevacizumab (AVASTIN™), trastuzumab (HERCEPTIN™), pegrilgrastim (NEULASTA™), or any other suitable polypeptide including biosimilars and biobetters.

[0053] Other suitable polypeptides are those listed below and in Table 1 of U.S. Patent Publication No. 2016/0097074:

TABLE I

Protein Product	Reference Listed Drug
interferon gamma-1b	Actimmune ®
alteplase; tissue plasminogen activator	Activase ®/Cathflo ®
Recombinant antihemophilic factor	Advate
human albumin	Albutein ®
Laronidase	Aldurazyme ®
Interferon alfa-N3, human leukocyte derived	Alferon N ®
human antihemophilic factor	Alphanate ®
virus-filtered human coagulation factor IX	AlphaNine ® SD
Alefacept; recombinant, dimeric fusion protein LFA3-Ig	Amevive ®
Bivalirudin	Angiomax ®
darbepoetin alfa	Aranesp ™
Bevacizumab	Avastin ™
interferon beta-1a; recombinant	Avonex ®
coagulation factor IX	BeneFix ™
Interferon beta-1b	Betaseron ®
Tositumomab	BEXXAR ®
antihemophilic factor	Bioclote ™
human growth hormone	BioTropin ™
botulinum toxin type A	BOTOX ®
Alemtuzumab	Campath ®

TABLE I

Protein Product	Reference Listed Drug
acritumomab; technetium-99 labeled	CEA-Scan ®
alglucerase; modified form of beta-glucocerebrosidase	Ceredase ®
imiglucerase; recombinant form of beta-glucocerebrosidase	Cerezyme ®
crotalidae polyvalent immune Fab, ovine	CroFab™
digoxin immune fab [ovine]	DigiFab™
Rasburicase	Elitek ®
Etanercept	ENBREL ®
epoietin alfa	Epogen ®
Cetuximab	Erbitux™
algasidase beta	Fabrazyme ®
Urofollitropin	Fertinex™
follitropin beta	Follistim™
Teriparatide	FORTEO ®
human somatotropin	GenoTropin ®
Glucagon	GlucaGen ®
follitropin alfa	Gonal-F ®
antihemophilic factor	Helixate ®
Antihemophilic Factor; Factor XIII	HEMOFIL
adefovir dipivoxil	Hepsera™
Trastuzumab	Herceptin ®
Insulin	Humalog ®
antihemophilic factor/von Willebrand factor complex-human	Humate-P ®
Somatotropin	Humatrope ®
Adalimumab	HUMIRA™
human insulin	Humulin ®
recombinant human hyaluronidase	Hylenex™
interferon alfacon-1	Infergen ®
eptifibatide	Integrilin™
alpha-interferon	Intron A ®
Palifermin	Kepivance
Anakinra	Kineret™
antihemophilic factor	Kogenate ® FS

TABLE I

Protein Product	Reference Listed Drug
insulin glargine	Lantus ®
granulocyte macrophage colony-stimulating factor	Leukine ®/Leukine ® Liquid
lutropin alfa for injection	Luveris
OspA lipoprotein	LYMErix <sup>TM</sup>
Ranibizumab	LUCENTIS ®
gemtuzumab ozogamicin	Mylotarg <sup>TM</sup>
Galsulfase	Naglazyme <sup>TM</sup>
Nesiritide	Natrecor ®
Pegfilgrastim	Neulasta <sup>TM</sup>
Oprelvekin	Neumega ®
Filgrastim	Neupogen ®
Fanolesomab	NeuroSpec <sup>TM</sup> (formerly LeuTech ®)
somatropin [rDNA]	Norditropin ®/Norditropin Nordiflex ®
Mitoxantrone	Novantrone ®
insulin; zinc suspension;	Novolin L ®
insulin; isophane suspension	Novolin N ®
insulin, regular;	Novolin R ®
Insulin	Novolin ®
coagulation factor VIIa	NovoSeven ®
Somatropin	Nutropin ®
immunoglobulin intravenous	Octagam ®
PEG-L-asparaginase	Oncaspar ®
abatacept, fully human soluble fusion protein	Orencia <sup>TM</sup>
muromomab-CD3	Orthoclone OKT3 ®
high-molecular weight hyaluronan	Orthovisc ®
human chorionic gonadotropin	Ovidrel ®
live attenuated Bacillus Calmette-Guerin	Pacis ®
peginterferon alfa-2a	Pegasys ®
pegylated version of interferon alfa-2b	PEG-Intron <sup>TM</sup>
Abarelix (injectable suspension); gonadotropin-releasing hormone	Plenaxis <sup>TM</sup>
antagonist	

TABLE I

Protein Product	Reference Listed Drug
epoietin alfa	Procrit ®
Aldesleukin	Proleukin, IL-2 ®
Somatrem	Protropin ®
dornase alfa	Pulmozyme ®
Efalizumab; selective, reversible T-cell blocker	RAPTIVA™
combination of ribavirin and alpha interferon	Rebetron™
Interferon beta 1a	Rebif ®
antihemophilic factor	Recombinate ® rAHF/
antihemophilic factor	ReFacto ®
Lepirudin	Refludan ®
Infliximab	REMICADE ®
Abciximab	ReoPro™
Retepase	Retavase™
Rituxima	Rituxan™
interferon alfa-2 <sup>a</sup>	Roferon-A ®
Somatropin	Saizen ®
synthetic porcine secretin	SecreFlo™
Basiliximab	Simulect ®
Eculizumab	SOLIRIS (R)
Pegvisomant	SOMAVERT ®
Palivizumab; recombinantly produced, humanized mAb	Synagis™
thyrotropin alfa	Thyrogen ®
Tenecteplase	TNKase™
Natalizumab	TYSABRI ®
human immune globulin intravenous 5% and 10% solutions	Venoglobulin-S ®
interferon alfa-n1, lymphoblastoid	Wellferon ®
drotrecogin alfa	Xigris™
Omalizumab; recombinant DNA-derived humanized monoclonal	Xolair ®
antibody targeting immunoglobulin-E	
Daclizumab	Zenapax ®
ibritumomab tiuxetan	Zevalin™
Somatotropin	Zorbtive™ (Serostim ®)

[0054] In embodiments, the polypeptide is a hormone, blood clotting/coagulation factor, cytokine/growth factor, antibody molecule, fusion protein, protein vaccine, or peptide as shown in Table 2.

Table 2. Exemplary Products

<b>Therapeutic Product type</b>	<b>Product</b>	<b>Trade Name</b>
Hormone	Erythropoietin, Epoetin- $\alpha$ Darbepoetin- $\alpha$ Growth hormone (GH), somatotropin  Human follicle-stimulating hormone (FSH) Human chorionic gonadotropin Lutropin- $\alpha$ Glucagon Growth hormone releasing hormone (GHRH) Secretin Thyroid stimulating hormone (TSH), thyrotropin	Epogen, Procrit Aranesp Genotropin , Humatrope, Norditropin, NovIVitropin, Nutropin, Omnitrope, Protropin, Siazen, Serostim, Valtropin Gonal-F, Follistim  Ovidrel Luveris GlucaGen Geref ChiRhoStim (human peptide), SecreFlo (porcine peptide) Thyrogen
Blood Clotting/Coagulation Factors	Factor VIIa Factor VIII  Factor IX Antithrombin III (AT-III) Protein C concentrate	NovoSeven Bioclote, Helixate, Kogenate, Recombinate, ReFacto  Benefix Thrombate III Ceprotin
Cytokine/Growth factor	Type I alpha-interferon Interferon- $\alpha$ n3 (IFN $\alpha$ n3) Interferon- $\beta$ 1a (rIFN- $\beta$ ) Interferon- $\beta$ 1b (rIFN- $\beta$ ) Interferon- $\gamma$ 1b (IFN $\gamma$ ) Aldesleukin (interleukin 2(IL2), epidermal thymocyte activating factor; ETAF Palifermin (keratinocyte	Infergen Alferon N Avonex, Rebif Betaseron Actimmune Proleukin  Kepivance Regranex

	<p>growth factor; KGF)  Becaplemin (platelet-derived growth factor; PDGF)  Anakinra (recombinant IL1 antagonist)</p>	Anril, Kineret
Antibody molecules	<p>Bevacizumab (VEGFA mAb)  Cetuximab (EGFR mAb)  Panitumumab (EGFR mAb)  Alemtuzumab (CD52 mAb)  Rituximab (CD20 chimeric Ab)  Trastuzumab (HER2/Neu mAb)  Abatacept (CTLA Ab/Fc fusion)  Adalimumab (TNF<math>\alpha</math>mAb)  Etanercept (TNF receptor/Fc fusion)  Infliximab (TNF<math>\alpha</math>chimeric mAb)  Alefcept (CD2 fusion protein)  Efalizumab (CD11a mAb)  Natalizumab (integrin <math>\alpha</math>4 subunit mAb)  Eculizumab (C5mAb)  Muromonab-CD3</p>	<p>Avastin  Erbitux  Vectibix  Campath  Rituxan  Herceptin  Orencia  Humira  Enbrel    Remicade  Amevive  Raptiva  Tysabri  Soliris  Orthoclone, OKT3</p>
Other: Fusion proteins/Protein vaccines/Peptides	<p>Insulin  Hepatitis B surface antigen (HBsAg)  HPV vaccine  OspA  Anti-Rhesus(Rh) immunoglobulin G  Enfuvirtide  Spider silk, e.g., fibrion</p>	<p>Humulin, Novolin  Engerix, Recombivax HB    Gardasil  LYMERix  Rhophylac  Fuzeon    QMONOS</p>

[0055] In embodiments, the protein is multispecific protein, e.g., a bispecific antibody as shown in Table 3.

Table 3: Bispecific Formats

<b>Name (other names, sponsoring organizations)</b>	<b>BsAb format</b>	<b>Targets</b>	<b>Proposed mechanisms of action</b>	<b>Development stages</b>	<b>Diseases (or healthy volunteers)</b>
Catumaxomab (Removab <sup>®</sup> , Fresenius Biotech, Trion Pharma, Neopharm)	BsIgG: Triomab	CD3, EpCAM	Retargeting of T cells to tumor, Fc mediated effector functions	Approved in EU	Malignant ascites in EpCAM positive tumors
Ertumaxomab (Neovii Biotech, Fresenius Biotech)	BsIgG: Triomab	CD3, HER2	Retargeting of T cells to tumor	Phase I/II	Advanced solid tumors
Blinatumomab (Blinicyto <sup>®</sup> , AMG 103, MT 103, MEDI 538, Amgen)	BiTE	CD3, CD19	Retargeting of T cells to tumor	Approved in USA Phase II and III Phase II Phase I	Precursor B-cell ALL ALL DLBCL NHL
REGN1979 (Regeneron)	BsAb	CD3, CD20			
Solitumab (AMG 110, MT110, Amgen)	BiTE	CD3, EpCAM	Retargeting of T cells to tumor	Phase I	Solid tumors
MEDI 565 (AMG 211, MedImmune, Amgen)	BiTE	CD3, CEA	Retargeting of T cells to tumor	Phase I	Gastrointestinal adenocarcinoma
RO6958688 (Roche)	BsAb	CD3, CEA			
BAY2010112 (AMG 212, Bayer; Amgen)	BiTE	CD3, PSMA	Retargeting of T cells to tumor	Phase I	Prostate cancer
MGD006	DART	CD3, CD123	Retargeting of T	Phase I	AML

<b>Name (other names, sponsoring organizations)</b>	<b>BsAb format</b>	<b>Targets</b>	<b>Proposed mechanisms of action</b>	<b>Development stages</b>	<b>Diseases (or healthy volunteers)</b>
(Macrogenics)			cells to tumor		
MGD007 (Macrogenics)	DART	CD3, gpA33	Retargeting of T cells to tumor	Phase I	Colorectal cancer
MGD011 (Macrogenics)	DART	CD19, CD3			
SCORPION (Emergent Biosolutions, Trubion)	BsAb	CD3, CD19	Retargeting of T cells to tumor		
AFM11 (Affimed Therapeutics)	TandAb	CD3, CD19	Retargeting of T cells to tumor	Phase I	NHL and ALL
AFM12 (Affimed Therapeutics)	TandAb	CD19, CD16	Retargeting of NK cells to tumor cells		
AFM13 (Affimed Therapeutics)	TandAb	CD30, CD16A	Retargeting of NK cells to tumor cells	Phase II	Hodgkin's Lymphoma
GD2 (Barbara Ann Karmanos Cancer Institute)	T cells preloaded with BsAb	CD3, GD2	Retargeting of T cells to tumor	Phase I/II	Neuroblastoma and osteosarcoma
pGD2 (Barbara Ann Karmanos Cancer Institute)	T cells preloaded with BsAb	CD3, Her2	Retargeting of T cells to tumor	Phase II	Metastatic breast cancer
EGFRBi-armed autologous activated T cells (Roger Williams Medical Center)	T cells preloaded with BsAb	CD3, EGFR	Autologous activated T cells to EGFR-positive tumor	Phase I	Lung and other solid tumors
Anti-EGFR-armed activated T-cells (Barbara Ann Karmanos)	T cells preloaded with BsAb	CD3, EGFR	Autologous activated T cells to EGFR-	Phase I	Colon and pancreatic cancers

Name (other names, sponsoring organizations)	BsAb format	Targets	Proposed mechanisms of action	Development stages	Diseases (or healthy volunteers)
Cancer Institute)			positive tumor		
rM28 (University Hospital Tübingen)	Tandem scFv	CD28, MAPG	Retargeting of T cells to tumor	Phase II	Metastatic melanoma
IMCgp100 (Immunocore)	ImmTAC	CD3, peptide MHC	Retargeting of T cells to tumor	Phase I/II	Metastatic melanoma
DT2219ARL (NCI, University of Minnesota)	2 scFv linked to diphtheria toxin	CD19, CD22	Targeting of protein toxin to tumor	Phase I	B cell leukemia or lymphoma
XmAb5871 (Xencor)	BsAb	CD19, CD32b			
NI-1701 (NovImmune)	BsAb	CD47, CD19			
MM-111 (Merrimack)	BsAb	ErbB2, ErbB3			
MM-141 (Merrimack)	BsAb	IGF-1R, ErbB3			
NA (Merus)	BsAb	HER2, HER3			
NA (Merus)	BsAb	CD3, CLEC12A			
NA (Merus)	BsAb	EGFR, HER3			
NA (Merus)	BsAb	PD1, undisclosed			
NA (Merus)	BsAb	CD3, undisclosed			

<b>Name (other names, sponsoring organizations)</b>	<b>BsAb format</b>	<b>Targets</b>	<b>Proposed mechanisms of action</b>	<b>Development stages</b>	<b>Diseases (or healthy volunteers)</b>
Duligotuzumab (MEHD7945A, Genentech, Roche)	DAF	EGFR, HER3	Blockade of 2 receptors, ADCC	Phase I and II Phase II	Head and neck cancer Colorectal cancer
LY3164530 (Eli Lilly)	Not disclosed	EGFR, MET	Blockade of 2 receptors	Phase I	Advanced or metastatic cancer
MM-111 (Merrimack Pharmaceuticals)	HSA body	HER2, HER3	Blockade of 2 receptors	Phase II Phase I	Gastric and esophageal cancers Breast cancer
MM-141, (Merrimack Pharmaceuticals)	IgG-scFv	IGF-1R, HER3	Blockade of 2 receptors	Phase I	Advanced solid tumors
RG7221 (RO5520985, Roche)	CrossMab	Ang2, VEGF A	Blockade of 2 proangiogenics	Phase I	Solid tumors
RG7716 (Roche)	CrossMab	Ang2, VEGF A	Blockade of 2 proangiogenics	Phase I	Wet AMD
OMP-305B83 (OncoMed)	BsAb	DLL4/VEGF			
TF2 (Immunomedics)	Dock and lock	CEA, HSG	Pretargeting tumor for PET or radioimaging	Phase II	Colorectal, breast and lung cancers
ABT-981 (AbbVie)	DVD-Ig	IL-1 $\alpha$ , IL-1 $\beta$	Blockade of 2 proinflammatory cytokines	Phase II	Osteoarthritis
ABT-122 (AbbVie)	DVD-Ig	TNF, IL-17A	Blockade of 2 proinflammatory cytokines	Phase II	Rheumatoid arthritis
COVA322	IgG-fynomer	TNF, IL17A	Blockade of 2 proinflammatory	Phase I/II	Plaque psoriasis

Name (other names, sponsoring organizations)	BsAb format	Targets	Proposed mechanisms of action	Development stages	Diseases (or healthy volunteers)
			cytokines		
SAR156597 (Sanofi)	Tetravalent bispecific tandem IgG	IL-13, IL-4	Blockade of 2 proinflammatory cytokines	Phase I	Idiopathic pulmonary fibrosis
GSK2434735 (GSK)	Dual-targeting domain	IL-13, IL-4	Blockade of 2 proinflammatory cytokines	Phase I	(Healthy volunteers)
Ozoralizumab (ATN103, Ablynx)	Nanobody	TNF, HSA	Blockade of proinflammatory cytokine, binds to HSA to increase half-life	Phase II	Rheumatoid arthritis
ALX-0761 (Merck Serono, Ablynx)	Nanobody	IL-17A/F, HSA	Blockade of 2 proinflammatory cytokines, binds to HSA to increase half-life	Phase I	(Healthy volunteers)
ALX-0061 (AbbVie, Ablynx)	Nanobody	IL-6R, HSA	Blockade of proinflammatory cytokine, binds to HSA to increase half-life	Phase I/II	Rheumatoid arthritis
ALX-0141 (Ablynx, Eddingpharm)	Nanobody	RANKL, HSA	Blockade of bone resorption, binds to HSA to increase half-life	Phase I	Postmenopausal bone loss
RG6013/ACE910 (Chugai, Roche)	ART-Ig	Factor IXa, factor X	Plasma coagulation	Phase II	Hemophilia

[0056] In particular, for protein manufacturing, technical, quality and economical aspects may be considered when implementing single-use technologies into a mammalian

manufacturing facility. Most of the mammalian manufacturing facilities are designed for the manufacture of multiple products. Consequently these facilities allow, to a certain extent, for flexibility regarding type of product, volume requirements and sequence/type of unit operations. The facility and room design of the various manufacturing facilities can be also taken into consideration when implementing single-use technology at the time of construction to ensure that these facilities allow for potential future use of one or more pieces of single-use equipment.

[0057] For cell therapy manufacturing, the facilities may be designed with a focus on flexibility and are able to handle products at various stages in the clinical pipeline. For processes previously developed in 2D culture systems and at early clinical stages, the main single-use component for the upstream expansion would be multilayer vessels (cell factories). Currently, the manufacturing facilities are able to handle various types and batch sizes of these vessels. However, as these processes get closer to commercialization and the need for larger yields-per-lot grows the switch to single-use bioreactor and microcarrier based processes may be necessary. Thus, it may be preferable to develop a single-use 3D bioreactor platform capable of supporting production scales from 1L to 50L. More preferably, to expand the production scale to 200L. Preferably, for cell therapy manufacturing, the implementation of single-use technology is carried out as early as possible to ensure that the product is commercialization-ready from the very beginning and that comparability issues are averted late in the development cycle.

[0058] The present invention relates to a manufacturing facility for the production of biopharmaceuticals and or APIs that offers both batch and continuous manufacturing using single-use disposable technology. As one example, the manufacturing facility according to the present invention is a biopharmaceutical facility with the capacity capable of

manufacturing bulk recombinant proteins and/or monoclonal antibody products. As another example, the manufacturing facility according to the present invention is a biopharmaceutical facility with the capacity capable of manufacturing cell therapy. As an additional example, the manufacturing facility according to the present invention is a biopharmaceutical facility with the capacity capable of manufacturing APIs.

**[0059]** In one aspect of the invention, the manufacturing facility may include single-use equipment or devices configured to support continuous production of biopharmaceuticals. The biopharmaceutical products include, but are not limited to, recombinant proteins, monoclonal antibodies, protein-drug conjugates, viral based therapeutics and cell therapies. Preferably, the single-use equipment or devices would dominate small- and mid-scale bioprocessing and occupy larger scale manufacturing. As one example, as shown in Figure 2, the implementation of various single-use equipment in connection with small-, mid- and large-scale bioreactors. In another example, studies have shown that antibody production through the use of Glutamine Synthetase- Chinese Hamster Ovary (GS-CHO) cell lines increases with robust manufacturing process which can be achieved using one of the continuous single-use disposable manufacturing facility of the present invention (*see e.g.*, Figure 4).

**[0060]** In one aspect of the invention, a method to manufacture a biopharmaceutical product is provided including: inserting a material into an inoculum device for processing; transferring the material from the inoculum device to an inoculum expansion device for further processing; then transferring the material from the inoculum expansion device to a production stage bioreactor device for further processing; then transferring the material from the production stage bioreactor device to a primary recovery device for further processing; then transferring the material from the primary recovery device to a capturing device for

further processing; then transferring the material from the capturing device to an ultrafiltration and diafiltration device for further processing; then transferring the material from the ultrafiltration and diafiltration device to a polishing membrane device for further processing; then transferring the material from the polishing membrane device to a polishing using cation exchange device for further processing; then transferring the material from the polishing using cation exchange device to a virus reduction filtration device for further processing; then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

**[0061]** In another aspect of the invention, a method to manufacture a biopharmaceutical product is provided including: inserting a material into an inoculum device for processing; transferring the material from the inoculum device to an inoculum expansion device for further processing; then transferring the material from the inoculum expansion device to a production stage perfusion device for further processing; then transferring the material from the production stage perfusion device to a volume exchange device for further processing; then transferring the material from the volume exchange device to a continuous filtration device for further processing; then transferring the material from the continuous filtration device to a virus reduction filtration device for further processing; then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

[0062] In another aspect of the invention, a method to manufacture a biopharmaceutical product is provided including: inserting a material into an inoculum device for processing; transferring the material from the inoculum device to an inoculum expansion device for further processing; then transferring the material from the inoculum expansion device to a production stage bioreactor device for further processing; then transferring the material from the production stage bioreactor device to a primary recovery device for further processing; then transferring the material from the primary recovery device to a volume exchange device for further processing; then transferring the material from the volume exchange device to a continuous purification device for further processing; then transferring the material from the continuous purification device to a virus reduction filtration device for further processing; then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

[0063] In another aspect of the invention, a method to manufacture a biopharmaceutical product is provided including: inserting a material into an inoculum device for processing; transferring the material from the inoculum device to an inoculum expansion device for further processing; then transferring the material from the inoculum expansion device to a production stage perfusion device for further processing; then transferring the material from the production stage perfusion device to a volume exchange device for further processing; then transferring the material from the volume exchange device to a continuous purification device for further processing; then transferring the material from the continuous purification device to a virus reduction filtration device for further processing; then transferring the material from the virus reduction filtration device to an ultrafiltration

and diafiltration device for further processing; and then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

[0064] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector; said at least one inoculum expansion device is connected to at least one production stage bioreactor device through at least one piece of tubing and a connector; said at least one production stage bioreactor device is connected to at least one primary recovery device through at least one piece of tubing and a connector; said at least one primary recovery device is connected to at least one capturing device through at least one piece of tubing and a connector; said at least one capturing device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector; said at least one ultrafiltration and diafiltration device is connected to at least one polishing membranes device through at least one piece of tubing and a connector; said at least one polishing membranes device is connected to at least one polishing using cation exchange device through at least one piece of tubing and a connector; said at least one polishing using cation exchange device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector; and said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector; said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

[0065] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: A method of making biopharmaceuticals

comprising: connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device; connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device; connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device; connecting said at least one primary recovery device to at least one capturing device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the capturing device; connecting said at least one capturing device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the capturing device to the ultrafiltration and diafiltration device; connecting said at least one ultrafiltration and diafiltration device to at least one polishing membranes device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the polishing membrane device; connecting said at least one polishing membranes device to at least one polishing using cation exchange device using at least one piece of tubing and a connector such that material can pass from the polishing membranes device to the polishing using cation exchange device; and connecting said at least one polishing using cation exchange device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the polishing using cation exchange device to the virus reduction filtration device; connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device such that

material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

[0066] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector; said at least one inoculum expansion device is connected to at least one production stage perfusion device through at least one piece of tubing and a connector; said at least one production stage perfusion device is connected to at least one volume exchange device through at least one piece of tubing and a connector; said at least one volume exchange device is connected to at least one continuous filtration device through at least one piece of tubing and a connector; said at least one continuous filtration device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector; said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector; and said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

[0067] In another aspect of the invention, a method of making biopharmaceuticals is provided comprising: connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device; connecting said at least one inoculum expansion device to at least one production stage perfusion device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion

device to the production stage perfusion device; connecting said at least one production stage perfusion device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the production stage perfusion device to the volume exchange device; connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device; connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the continuous purification device to the virus reduction filtration device; connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

**[0068]** In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector; said at least one inoculum expansion device is connected to at least one production stage bioreactor device through at least one piece of tubing and a connector; said at least one production stage bioreactor device is connected to at least one primary recovery device through at least one piece of tubing and a connector; said at least one primary recovery device is connected to at least one volume exchange device through at least one piece of tubing and a connector; said at least one volume exchange device is connected to at least one continuous purification

device through at least one piece of tubing and a connector; said at least one continuous purification device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector; said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector; and said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

[0069] In another aspect of the invention, a method of making biopharmaceuticals is provided comprising: connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device; connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device; connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device; connecting said at least one primary recovery device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the volume exchange device; connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device; connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the continuous purification device to

the virus reduction filtration device; connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

[0070] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector; said at least one inoculum expansion device is connected to at least one production stage perfusion device through at least one piece of tubing and a connector; said at least one production stage perfusion device is connected to at least one volume exchange device through at least one piece of tubing and a connector; said at least one volume exchange device is connected to at least one continuous purification device through at least one piece of tubing and a connector; said at least one continuous purification device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector; said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector; and said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

[0071] In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such

that material can pass from the inputting device to the inoculum expansion device; connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device; connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device; connecting said at least one primary recovery device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the volume exchange device; connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device; connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the continuous purification device to the virus reduction filtration device; connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

**[0072]** In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one equipment configured for inputting

cells; at least one equipment configured for inoculum expansion; at least one production stage bioreactor; at least one equipment configured for primary recovery; at least one equipment configured for capturing; at least one equipment configured for ultrafiltration and diafiltration; at least one equipment configured for polishing membranes; at least one equipment configured for polishing using cation exchange; at least one equipment configured for virus reduction filtration; and at least one equipment configured for automated bulk fill; and wherein the equipments are connected, and wherein the at least one equipment is connected through at least one piece of tubing and at least one connector such that the contents can pass from one piece of equipment to another via tubing.

[0073] In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: providing at least one equipment configured for inputting cells; providing at least one equipment configured for inoculum expansion; providing at least one production stage bioreactor; providing at least one equipment configured for primary recovery; providing at least one equipment configured for capturing; providing at least one equipment configured for ultrafiltration and diafiltration; providing at least one equipment configured for polishing membranes; providing at least one equipment configured for polishing using cation exchange; providing at least one equipment configured for virus reduction filtration; providing a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion; providing a connector between the at least one equipment configured for inoculum expansion and the at least one production stage bioreactor; providing a connector between the least one production stage bioreactor and the at least one equipment configured for primary recovery; providing a connector between the at least one equipment configured for primary recovery and the at least one equipment configured for capturing; providing a

connector between the at least one equipment configured for capturing and the at least one equipment configured for ultrafiltration and diafiltration; providing a connector between the at least one equipment configured for ultrafiltration and diafiltration and the at least one equipment configured for polishing membranes; providing a connector between the at least one equipment configured for polishing membranes and the at least one equipment configured for polishing using cation exchange; providing a connector between the at least one equipment configured for polishing using cation exchange and the at least one equipment configured for virus reduction filtration; providing at least one equipment configured for ultrafiltration and diafiltration; providing at least one equipment configured for automated bulk fill; providing a connector between the at least one equipment configured for virus reduction filtration and the at least one equipment configured for ultrafiltration and diafiltration; providing a connector between the at least one equipment configured for ultrafiltration and diafiltration and the at least one equipment configured for automated bulk fill.

**[0074]** In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: providing at least one equipment configured for inputting cells; providing at least one equipment configured for inoculum expansion; providing a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion.

**[0075]** In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one equipment configured for inputting cells; at least one equipment configured for inoculum expansion; at least one equipment configured for production stage perfusion; at least one equipment configured for volume exchange; at least one equipment configured for continuous purification; at least one

equipment configured for virus reduction filtration; at least one equipment configured for ultrafiltration and diafiltration; and at least one equipment configured for automated bulk fill; and wherein the equipments are connected, and wherein the at least one equipment is connected through at least one piece of tubing and at least one connector such that the contents can pass from one piece of equipment to another via tubing.

[0076] In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: providing at least one equipment configured for inputting cells; providing at least one equipment configured for inoculum expansion; providing at least one equipment configured for production stage perfusion; providing at least one equipment configured for volume exchange; providing at least one equipment configured for continuous purification; providing at least one equipment configured for virus reduction filtration; providing at least one equipment configured for ultrafiltration and diafiltration; providing at least one equipment configured for automated bulk fill; providing a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion; providing a connector between the at least one equipment configured for inoculum expansion and at least one equipment configured for production stage perfusion; providing a connector between the at least one equipment configured for production stage perfusion and the at least one equipment configured for volume exchange; providing a connector between the at least one equipment configured for volume exchange and the at least one equipment configured for continuous purification; providing a connector between the at least one equipment configured for continuous purification and the at least one equipment configured for virus reduction filtration; providing a connector between the at least one equipment configured for virus reduction filtration and the at least one equipment configured for ultrafiltration and diafiltration; providing a

connector between the at least one equipment configured for ultrafiltration and diafiltration and the at least one equipment configured for automated bulk fill.

[0077] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one equipment configured for inputting cells; at least one equipment configured for inoculum expansion; at least one production stage bioreactor; at least one equipment configured for primary recovery; at least one equipment configured for volume exchange; at least one equipment configured for continuous purification; at least one equipment configured for virus reduction filtration; at least one equipment configured for ultrafiltration and diafiltration; and at least one equipment configured for automated bulk fill; and wherein the equipments are connected, and wherein the at least one equipment is connected through at least one piece of tubing and at least one connector such that the contents can pass from one piece of equipment to another via tubing.

[0078] In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: providing at least one equipment configured for inputting cells; providing at least one equipment configured for inoculum expansion; providing at least one production stage bioreactor; providing at least one equipment configured for primary recovery stage; providing at least one equipment configured for volume exchange; providing at least one equipment configured for continuous purification; providing at least one equipment configured for virus reduction filtration; providing at least one equipment configured for ultrafiltration and diafiltration; providing at least one equipment configured for automated bulk fill; providing a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion; providing a connector between the at least one equipment configured

for inoculum expansion and the at least one production stage bioreactor; providing a connector between the at least one production stage bioreactor and at least one equipment configured for primary recovery; providing a connector between the at least one equipment configured for primary recovery and the at least one equipment configured for volume exchange; providing a connector between the at least one equipment configured for volume exchange and the at least one equipment configured for continuous purification; providing a connector between the at least one equipment configured for continuous purification and the at least one equipment configured for virus reduction filtration; providing a connector between the at least one equipment configured for virus reduction filtration and the at least one equipment configured for ultrafiltration and diafiltration; providing a connector between the at least one equipment configured for ultrafiltration and diafiltration and the at least one equipment configured for automated bulk fill.

[0079] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one equipment configured for inputting cells; at least one equipment configured for inoculum expansion; at least one equipment configured for production stage perfusion; at least one equipment configured for volume exchange; at least one equipment configured for continuous purification; at least one equipment configured for virus reduction filtration; at least one equipment configured for ultrafiltration and diafiltration; and at least one equipment configured for automated bulk fill; and wherein the equipments are connected, and wherein the at least one equipment is connected through at least one piece of tubing and at least one connector such that the contents can pass from one piece of equipment to another via tubing.

[0080] In another aspect of the invention, a method for manufacturing biopharmaceuticals is provided comprising: providing at least one equipment configured for inputting cells; providing at least one equipment configured for inoculum expansion; providing at least one production stage bioreactor; providing at least one equipment configured for primary recovery; providing at least one equipment configured for volume exchange; providing at least one equipment configured for continuous purification; providing at least one equipment configured for virus reduction filtration; providing at least one equipment configured for ultrafiltration and diafiltration; providing at least one equipment configured for automated bulk fill equipment; providing a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion; providing a connector between the at least one equipment configured for inoculum expansion and the at least one production stage bioreactor; providing a connector between the at least one production stage bioreactor and the at least one equipment configured for volume exchange; providing a connector between the at least one equipment configured for volume exchange and the at least one equipment configured for continuous purification; providing a connector between the at least one equipment configured for continuous purification and the at least one equipment configured for virus reduction filtration; providing a connector between the at least one equipment configured for virus reduction filtration and the at least one equipment configured for ultrafiltration and diafiltration; providing a connector between the at least one equipment configured for ultrafiltration and diafiltration and the at least one equipment configured for automated bulk fill.

[0081] In another aspect of the invention, a manufacturing system for biopharmaceuticals is provided comprising: at least one equipment configured for inputting

cells; at least one equipment configured for inoculum expansion; and a connector between the at least one equipment configured for inputting cells and the at least one equipment configured for inoculum expansion.

[0082] In yet another aspect of the invention, the device or equipment can be from at least two different manufacturers.

[0083] In yet another aspect of the invention, at least one device is not made for single-use.

[0084] In yet another aspect of the invention, the manufacturing system is operated as a closed system.

[0085] In yet another aspect of the invention, the manufacturing system further includes at least one sensor capable of controlling flow of material between two devices.

[0086] In yet another aspect of the invention, the manufacturing system is automated.

[0087] In yet another aspect of the invention, at least one device can be in more than one room.

[0088] In yet another aspect of the invention, the manufacturing system further includes at least one disposable bag that can be used to dispose of at least one device, tubing or connector.

### **Example 1**

[0089] A manufacturing facility that has completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 1 in the

following order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for the capture step (5), ultrafiltration and diafiltration equipment (6), polishing membranes (7), equipment for polishing using cation exchange (8), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0090] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to the equipment for the capture (5). Once captured, the contents are moved to the ultrafiltration and diafiltration equipment (6). The contents are next sent to the polishing membranes (7) and the equipment for polishing using cation exchange (8). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

### **Example 2**

[0091] A manufacturing facility that is a partly closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 1 in the following

order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for the capture step (5), ultrafiltration and diafiltration equipment (6), polishing membranes (7), equipment for polishing using cation exchange (8), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0092] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to the equipment for the capture (5). Once captured, the contents are moved to the ultrafiltration and diafiltration equipment (6). The contents are next sent to the polishing membranes (7) and the equipment for polishing using cation exchange (8). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

### **Example 3**

[0093] A manufacturing facility that is an only partly disposable and scalable production system having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 1 in the following

order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for the capture step (5), ultrafiltration and diafiltration equipment (6), polishing membranes (7), equipment for polishing using cation exchange (8), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0094] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to the equipment for the capture (5). Once captured, the contents are moved to the ultrafiltration and diafiltration equipment (6). The contents are next sent to the polishing membranes (7) and the equipment for polishing using cation exchange (8). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

#### **Example 4**

[0095] A manufacturing facility that has completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 2 in the

following order: input cells (1), inoculum expansion equipment (2), production stage perfusion equipment (12), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0096] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to production stage perfusion equipment (12). After that, the contents are transferred to the equipment for volume exchange (13). Then, the contents are sent to the continuous purification equipment (14). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

### **Example 5**

[0097] A manufacturing facility that is a partly closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 2 in the following order: input cells (1), inoculum expansion equipment (2), production stage perfusion equipment (12), equipment for volume exchange (13), continuous purification equipment

(14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[0098] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to production stage perfusion equipment (12). After that, the contents are transferred to the equipment for volume exchange (13). Then, the contents are sent to the continuous purification equipment (14). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

### **Example 6**

[0099] A manufacturing facility that is an only partly disposable and scalable production system having integrated disposables designed for each aspect of product production.

[00100] The equipment is connected to each other as shown in FIG. 2 in the following order: input cells (1), inoculum expansion equipment (2), production stage perfusion equipment (12), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[00101] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to production stage perfusion equipment (12). After that, the contents are transferred to the equipment for volume exchange (13). Then, the contents are sent to the continuous purification equipment (14). Then the contents are moved to the virus reduction filtration equipment (9). Next, the contents are moved to the ultrafiltration and diafiltration equipment (10). Then, the contents are moved to the automated bulk fill equipment (11). The ultrafiltration and diafiltration equipment (10) and the automated bulk fill equipment (11) can be in a separate room. Ideally, there are connectors that can move the contents directly, but it is also contemplated by this invention that the contents will be transferred by other means at this point.

### **Example 7**

[00102] A manufacturing facility that has completely closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 3 in the following order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[00103] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the

contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

### **Example 8**

**[00104]** A manufacturing facility that is a partly closed, fully disposable, and scalable production systems having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 3 in the following order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

**[00105]** Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

**Example 8**

[00106] A manufacturing facility that is an only partly disposable and scalable production system having integrated disposables designed for each aspect of product production. The equipment is connected to each other as shown in FIG. 3 in the following order: input cells (1), inoculum expansion equipment (2), production stage bioreactor equipment (3), primary recovery stage equipment (4), equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

[00107] Product is made by adding the input cells at Step 1. The equipment in Step 1 opens the containers that contain the input cells. The contents are moved to the inoculum expansion equipment (2) through tubes that connect these pieces of equipment. Then, the contents are moved to the production stage bioreactor equipment (3). The contents are then transferred to the primary recovery stage equipment (4). After which, the contents are sent to equipment for volume exchange (13), continuous purification equipment (14), virus reduction filtration equipment (9), ultrafiltration and diafiltration equipment (10), and automated bulk fill equipment (11).

It should be recognized that the one or more examples in the disclosure are non-limiting examples and that the present invention is intended to encompass variations and equivalents of these examples.

**Claims**

1. A manufacturing system for biopharmaceuticals comprising:

at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector;

said at least one inoculum expansion device is connected to at least one production stage bioreactor device through at least one piece of tubing and a connector;

said at least one production stage bioreactor device is connected to at least one primary recovery device through at least one piece of tubing and a connector;

said at least one primary recovery device is connected to at least one capturing device through at least one piece of tubing and a connector;

said at least one capturing device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector;

said at least one ultrafiltration and diafiltration device is connected to at least one polishing membranes device through at least one piece of tubing and a connector;

said at least one polishing membranes device is connected to at least one polishing using cation exchange device through at least one piece of tubing and a connector;

said at least one polishing using cation exchange device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector; and

said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector;

said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

2. The manufacturing system of claim 1, wherein the device can be from at least two different manufacturers.
3. The manufacturing system of claim 1, wherein at least one device is not made for single-use.
4. The manufacturing system of claim 1, wherein the system is operated as a closed system.
5. The manufacturing system of claim 1, further comprising at least one sensor capable of controlling flow of material between two devices.
6. The manufacturing system of claim 1, wherein the system is automated.
7. The manufacturing system of claim 1, wherein at least one device can be in more than one room.
8. The manufacturing system of claim 1, further comprising at least one disposable bag that can be used to dispose of at least one device, tubing or connector.
9. A method of making biopharmaceuticals comprising:  
connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device;

connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device;

connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device;

connecting said at least one primary recovery device to at least one capturing device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the capturing device;

connecting said at least one capturing device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the capturing device to the ultrafiltration and diafiltration device;

connecting said at least one ultrafiltration and diafiltration device to at least one polishing membranes device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the polishing membrane device;

connecting said at least one polishing membranes device to at least one polishing using cation exchange device using at least one piece of tubing and a connector such that material can pass from the polishing membranes device to the polishing using cation exchange device; and

connecting said at least one polishing using cation exchange device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the polishing using cation exchange device to the virus reduction filtration device.

10. The method of claim 9, further comprising:
  - connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and
  - connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.
11. The method of claim 9, wherein the method is automated.
12. The method of claim 10, wherein the method is automated.
13. A method of making biopharmaceuticals comprising:
  - connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device.
14. A manufacturing system for biopharmaceuticals comprising:
  - at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector;
  - said at least one inoculum expansion device is connected to at least one production stage perfusion device through at least one piece of tubing and a connector;

said at least one production stage perfusion device is connected to at least one volume exchange device through at least one piece of tubing and a connector;

said at least one volume exchange device is connected to at least one continuous filtration device through at least one piece of tubing and a connector;

said at least one continuous filtration device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector;

said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector;  
and

said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

15. The manufacturing system of claim 14, wherein the device can be from at least two different manufacturers.

16. The manufacturing system of claim 14, wherein at least one device is not made for single-use.

17. The manufacturing system of claim 14, wherein the system is operated as a closed system.

18. The manufacturing system of claim 14, further comprising at least one sensor capable of controlling flow of material between two devices.

19. The manufacturing system of claim 14, wherein the system is automated.
20. The manufacturing system of claim 14, wherein at least one device can be in more than one room.
21. The manufacturing system of claim 14, further comprising at least one disposable bag that can be used to dispose of at least one device, tubing or connector.
22. A method of making biopharmaceuticals comprising:
- connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device;
  - connecting said at least one inoculum expansion device to at least one production stage perfusion device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage perfusion device;
  - connecting said at least one production stage perfusion device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the production stage perfusion device to the volume exchange device;
  - connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device;
  - connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that

material can pass from the continuous purification device to the virus reduction filtration device;

connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and

connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

23. A manufacturing system for biopharmaceuticals comprising:

at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector;

said at least one inoculum expansion device is connected to at least one production stage bioreactor device through at least one piece of tubing and a connector;

said at least one production stage bioreactor device is connected to at least one primary recovery device through at least one piece of tubing and a connector;

said at least one primary recovery device is connected to at least one volume exchange device through at least one piece of tubing and a connector;

said at least one volume exchange device is connected to at least one continuous purification device through at least one piece of tubing and a connector;

said at least one continuous purification device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector;

said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector;  
and

said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

24. The manufacturing system of claim 23, wherein the device can be from at least two different manufacturers.

25. The manufacturing system of claim 23, wherein at least one device is not made for single-use.

26. The manufacturing system of claim 23, wherein the system is operated as a closed system.

27. The manufacturing system of claim 23, further comprising at least one sensor capable of controlling flow of material between two devices.

28. The manufacturing system of claim 23, wherein the system is automated.

29. The manufacturing system of claim 23, wherein at least one device can be in more than one room.

30. The manufacturing system of claim 23, further comprising at least one disposable bag that can be used to dispose of at least one of device, tubing or connector.

31. A method of making biopharmaceuticals comprising:

connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device;

connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device;

connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device;

connecting said at least one primary recovery device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the volume exchange device;

connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device;

connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the continuous purification device to the virus reduction filtration device;

connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and

connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

32. A manufacturing system for biopharmaceuticals comprising:

at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector;

said at least one inoculum expansion device is connected to at least one production stage perfusion device through at least one piece of tubing and a connector;

said at least one production stage perfusion device is connected to at least one volume exchange device through at least one piece of tubing and a connector;

said at least one volume exchange device is connected to at least one continuous purification device through at least one piece of tubing and a connector;

said at least one continuous purification device is connected to at least one virus reduction filtration device through at least one piece of tubing and a connector;

said at least one virus reduction filtration device is connected to at least one ultrafiltration and diafiltration device through at least one piece of tubing and a connector;

and

said at least one ultrafiltration and diafiltration device is connected to at least one automated bulk fill device through at least one piece of tubing and a connector.

33. The manufacturing system of claim 32, wherein the device can be from at least two different manufacturers.
34. The manufacturing system of claim 32, wherein at least one device is not made for single-use.
35. The manufacturing system of claim 32, wherein there the system operated as a closed system.
36. The manufacturing system of claim 32, further comprising at least one sensor capable of controlling flow of material between two devices.
37. The manufacturing system of claim 32, wherein the system is automated.
38. The manufacturing system of claim 32, wherein at least one device can be in more than one room.
39. The manufacturing system of claim 32, further comprising at least one disposable bag that can be used to dispose of at least one device, tubing or connector.

40. A method for manufacturing biopharmaceuticals comprising:
- connecting at least one inputting device to at least one inoculum expansion device using at least one piece of tubing and a connector such that material can pass from the inputting device to the inoculum expansion device;
  - connecting said at least one inoculum expansion device to at least one production stage bioreactor device using at least one piece of tubing and a connector such that material can pass from the inoculum expansion device to the production stage bioreactor device;
  - connecting said at least one production stage bioreactor device to at least one primary recovery device using at least one piece of tubing and a connector such that material can pass from the production stage bioreactor device to the primary recovery device;
  - connecting said at least one primary recovery device to at least one volume exchange device using at least one piece of tubing and a connector such that material can pass from the primary recovery device to the volume exchange device;
  - connecting said at least one volume exchange device to at least one continuous purification device using at least one piece of tubing and a connector such that material can pass from the volume exchange device to the continuous purification device;
  - connecting said at least one continuous purification device to at least one virus reduction filtration device using at least one piece of tubing and a connector such that material can pass from the continuous purification device to the virus reduction filtration device;
  - connecting said at least one virus reduction filtration device to at least one ultrafiltration and diafiltration device using at least one piece of tubing and a connector such that material can pass from the virus reduction filtration device to the ultrafiltration and diafiltration device; and

connecting said at least one ultrafiltration and diafiltration device to at least one automated bulk fill device using at least one piece of tubing and a connector such that material can pass from the ultrafiltration and diafiltration device to the automated bulk fill device.

41. A manufacturing system for biopharmaceuticals comprising:

at least one inputting device connected to at least one inoculum expansion device through at least one piece of tubing and a connector.

42. The manufacturing system of claim 41, further comprising a sensor.

43. A method to manufacture a biopharmaceutical product comprising:

inserting a material into an inoculum device for processing;

transferring the material from the inoculum device to an inoculum expansion device for further processing;

then transferring the material from the inoculum expansion device to a production stage bioreactor device for further processing;

then transferring the material from the production stage bioreactor device to a primary recovery device for further processing;

then transferring the material from the primary recovery device to a capturing device for further processing;

then transferring the material from the capturing device to an ultrafiltration and diafiltration device for further processing;

then transferring the material from the ultrafiltration and diafiltration device to a polishing membrane device for further processing;

then transferring the material from the polishing membrane device to a polishing using cation exchange device for further processing;

then transferring the material from the polishing using cation exchange device to a virus reduction filtration device for further processing;

then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and

then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

44. A method to manufacture a biopharmaceutical product comprising:

inserting a material into an inoculum device for processing;

transferring the material from the inoculum device to an inoculum expansion device for further processing;

then transferring the material from the inoculum expansion device to a production stage perfusion device for further processing;

then transferring the material from the production stage perfusion device to a volume exchange device for further processing;

then transferring the material from the volume exchange device to a continuous filtration device for further processing;

then transferring the material from the continuous filtration device to a virus reduction filtration device for further processing;

then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and

then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

45. A method to manufacture a biopharmaceutical product comprising:

inserting a material into an inoculum device for processing;

transferring the material from the inoculum device to an inoculum expansion device for further processing;

then transferring the material from the inoculum expansion device to a production stage bioreactor device for further processing;

then transferring the material from the production stage bioreactor device to a primary recovery device for further processing;

then transferring the material from the primary recovery device to a volume exchange device for further processing;

then transferring the material from the volume exchange device to a continuous purification device for further processing;

then transferring the material from the continuous purification device to a virus reduction filtration device for further processing;

then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and

then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

46. A method to manufacture a biopharmaceutical product comprising:
- inserting a material into an inoculum device for processing;
  - transferring the material from the inoculum device to an inoculum expansion device for further processing;
  - then transferring the material from the inoculum expansion device to a production stage perfusion device for further processing;
  - then transferring the material from the production stage perfusion device to a volume exchange device for further processing;
  - then transferring the material from the volume exchange device to a continuous purification device for further processing;
  - then transferring the material from the continuous purification device to a virus reduction filtration device for further processing;
  - then transferring the material from the virus reduction filtration device to an ultrafiltration and diafiltration device for further processing; and
  - then transferring the material from the ultrafiltration and diafiltration device to an automated bulk fill device to obtain the biopharmaceutical product.

FIG. 1 Batch Processing

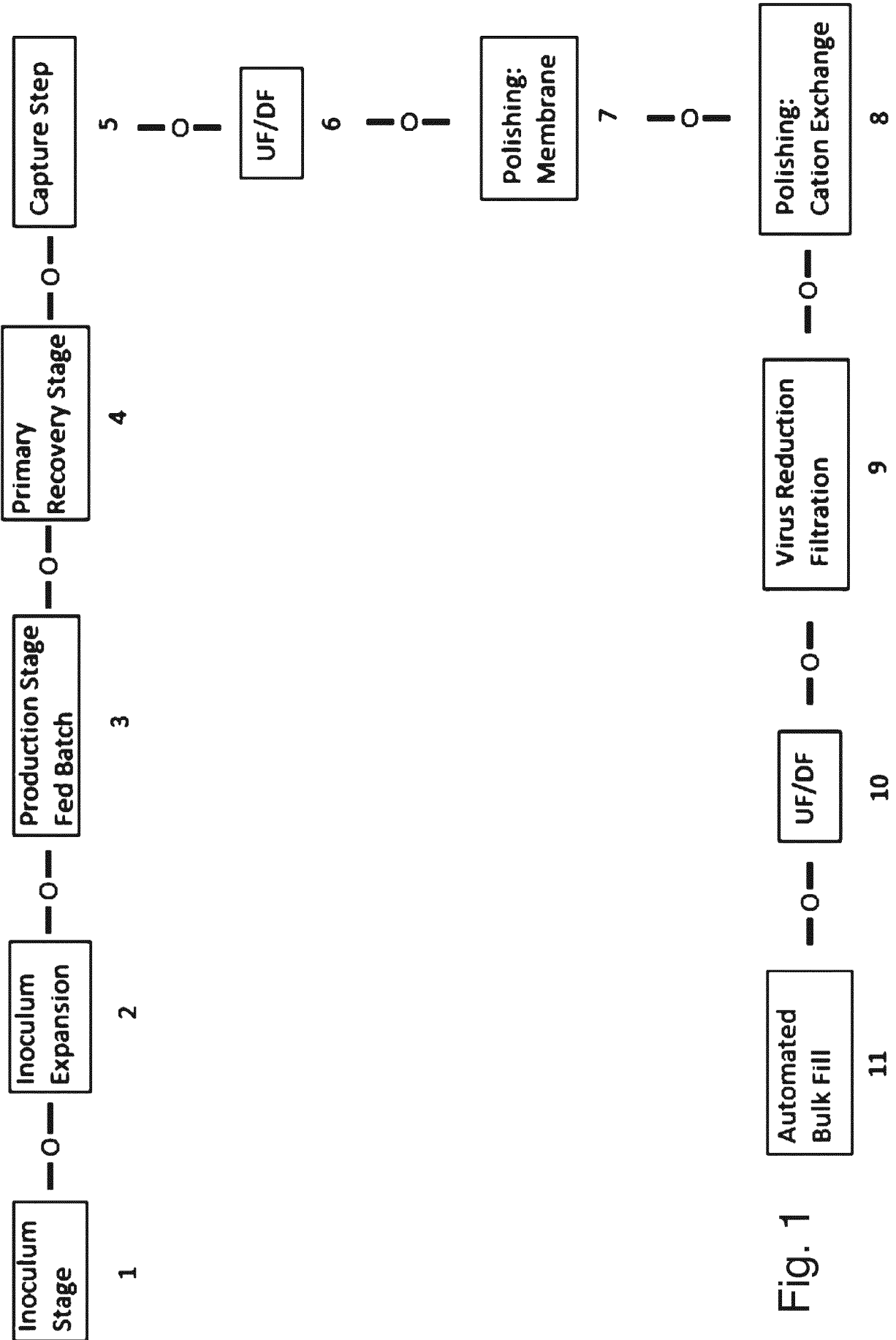


Fig. 1

FIG. 2 Continuous Processing

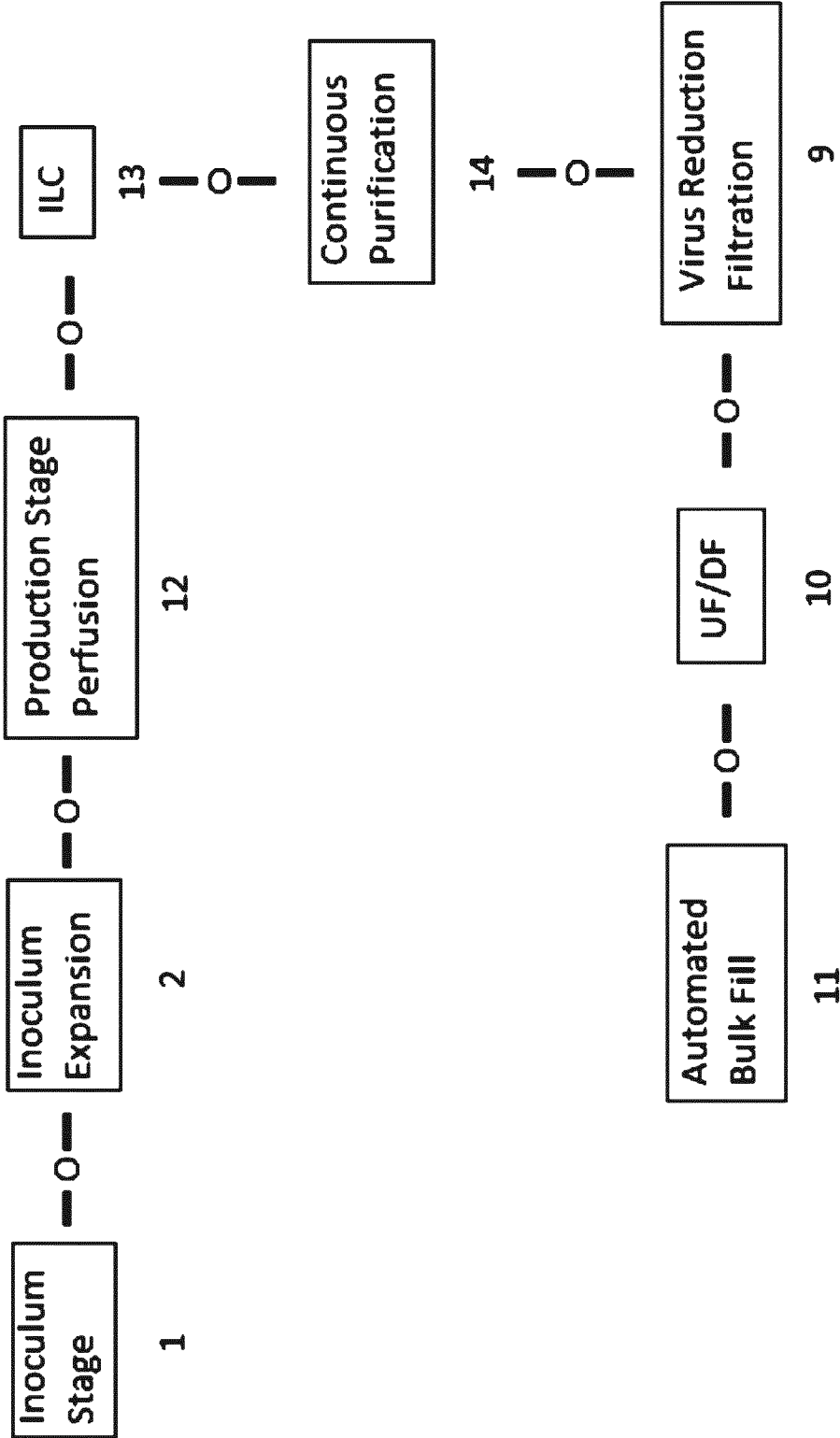


Fig. 2

FIG. 3 Hybrid Processing

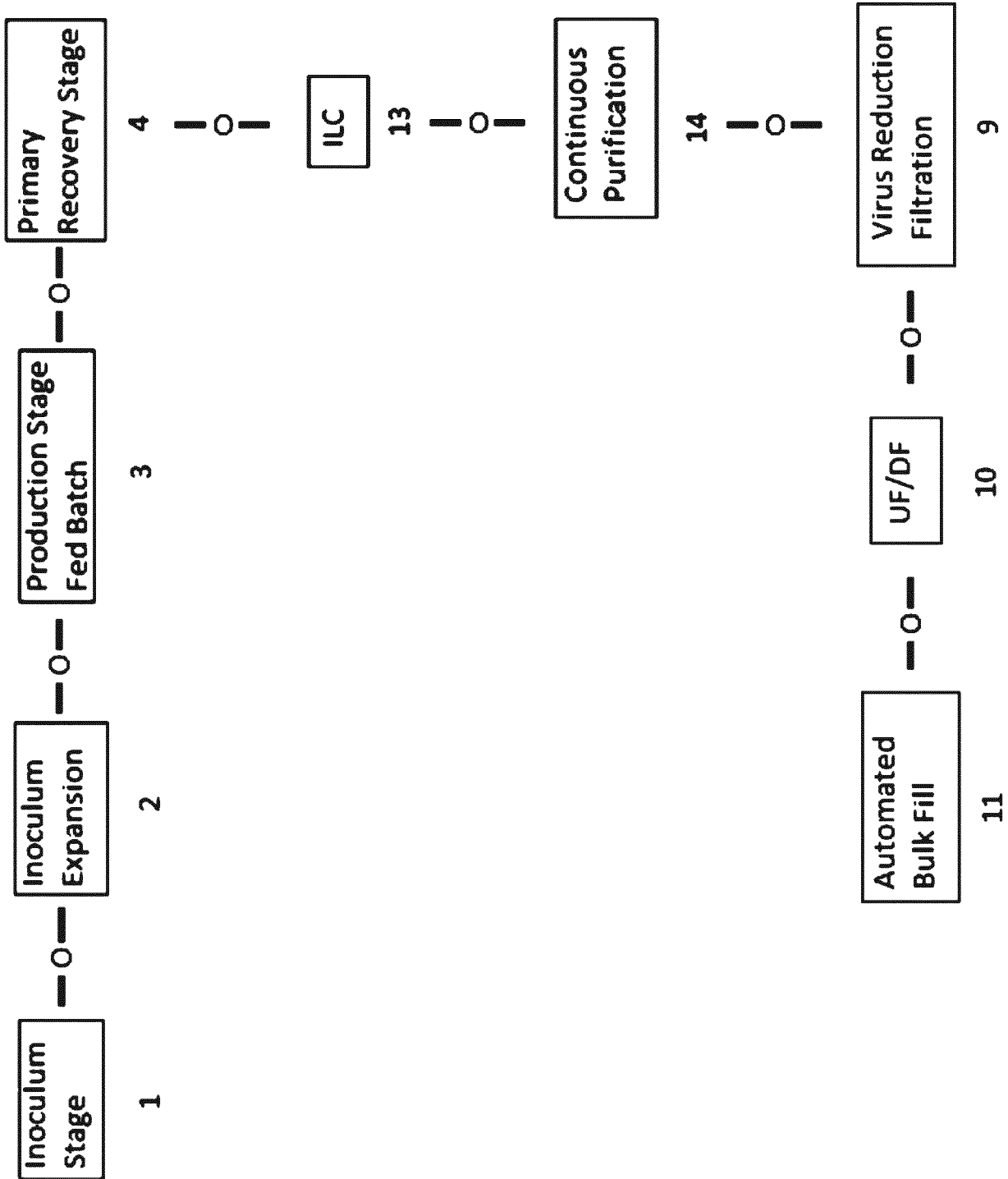


Fig. 3

FIG. 4 Cell viability using different media

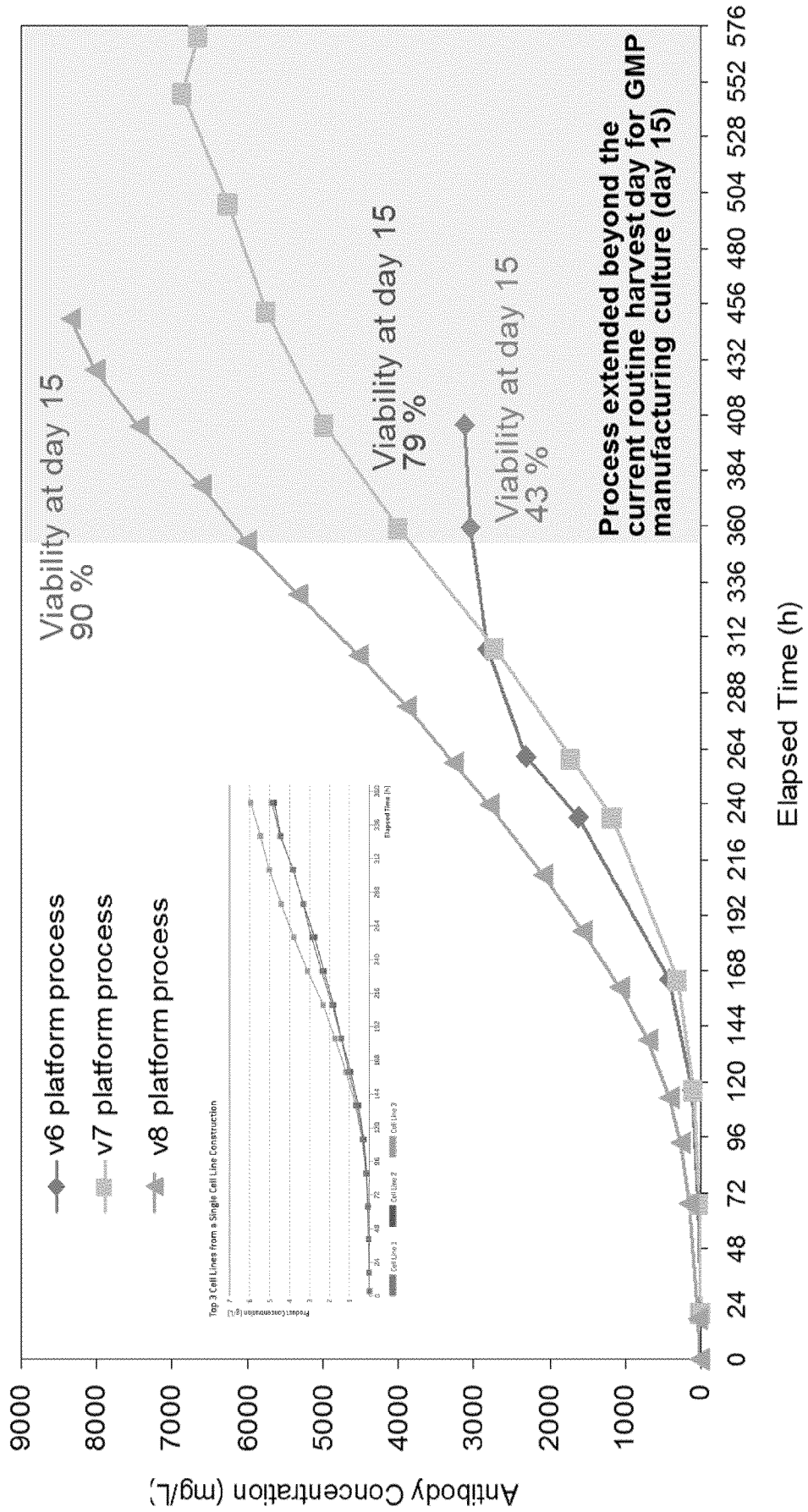


FIG. 5

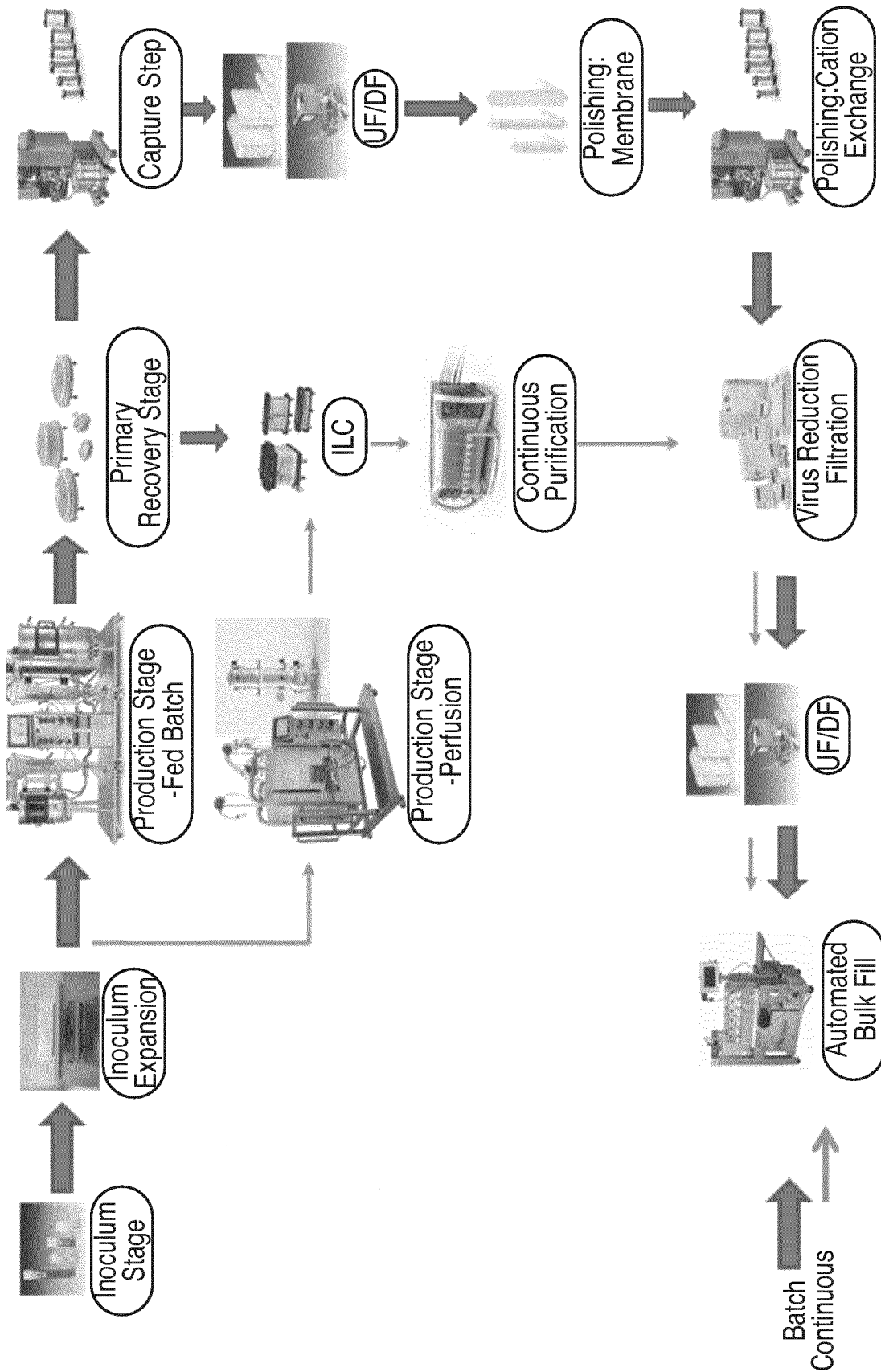


FIG. 6

Mammalian Unit Operations		Cellbanking, cryovials	Shake Flask, waves	Inoculum Bioreactor	Feed, media Preparation	Production Bioreactor	Transfers upstream	Centrifugation	Microfiltration or depth filtration	Virus filtration, depth filtration	Intermediate holds, operations *	Buffer preparation and holds	Chromatography	Transfers downstream	Bulk fill
Slough-Biopharma Single Use Bioreactor (50L-500L, pilot), 1000L cGMP		n.a.						n.a.							
Slough-Biopharma 500L, 800L (400L pilot) Stirred		n.a.						n.a.							
Slough-Biopharma 200L Airlift								n.a.							
Slough-Biopharma 2'000L Airlift															
Singapore-Biopharma 20'000L															
Porrino-Biopharma 10,000L															
Portsmouth-Biopharma 5'000L															
Portsmouth-Biopharma 20'000L															

\* e.g. virus inactivation

single-use, disposable  
 steel  
 hybrid or alternatively single-use equipment is used as an option