Cellular Biomechanical Systems
2D/3D Cell Culture • Tension • Compression • Shear Stress • Tissue Engineering

**Tension System**

**Compression System**

**Tension & Compression Systems:** Computer regulated bioreactors that apply cyclic or static tensile strains or compression to cells cultured in vitro (pages 4, 6, and 22).

**Tissue Train® Culture System:** 3D cell culture in a gel matrix with or without cyclic uniaxial tension (page 5).

**StageFlexer®**

**StagePresser™**

**ScanFlex™**

**FlexFlow™**

**Microscopy Devices:** Single-well devices of the Tension or Compression apparatus to observe signaling responses to strain in real time on a microscope stage (pages 10 and 11).

**ScanFlex™:** Scans and saves images of 3D tissue constructs (page 9).

**Flow Devices & Controllers:** Apply fluid shear stress to cells with the Streamer® and FlexFlow™ systems, regulate oscillatory and pulsatile flow with the Osci-Flow® (pages 11 - 13).

**6- and 24-well Culture Plates:** Grow and stretch your cells on six different matrix bonded growth surfaces (and untreated) for use with Flexcell’s® Tension, Tissue Train® and Compression systems (pages 17 - 21).

**Membranes:** Six different matrix bonded growth surfaces (and untreated) for use with StageFlexer® and FlexFlow™, untreated membranes for use with StagePresser™ (pages 20 and 21).

**Culture Slips®:** Surface treated slides for use with Streamer® and FlexFlow™ (page 21).
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### Prices: Please ask for a quotation.

*Transwell® is a registered trademark of Corning® Inc.*
Why Culture Cells in a Mechanically Active Environment?

Cells are subjected to compression, tension, and shear in the body and undergo acute and adaptive biochemical changes in response to deformation. Stressing cells in culture simulates the *in vivo* environment causing dramatic morphologic and biochemical responses. Flexcell’s® tension, compression, and fluid shear stress systems have broad applications since strain, compression, or fluid flow have been found to induce biochemical changes in cells derived from a variety of tissues including cardiac, skeletal, and smooth muscle, lung, vascular endothelium, skin, tendon, ligament, cartilage, and bone.

Tissue Engineering

Formation of tissues *in vitro* that are structurally and functionally viable requires several basic conditions, such as 1) cells 2) matrix 3) media and growth factors and 4) mechanical stimulation. These conditions are linked to each other and act in conjunction to form a structurally robust tissue that can withstand biomechanical forces. To generate a tissue *in vitro* that is more or less equivalent to the native tissues, one should create an environment that would mimic the *in vivo* conditions. Culturing cells in a mechanically active environment increases cell metabolism and alters cell shape and other properties. In addition, culturing cells in a 3D environment more closely simulates the native environment.

Why Fluid Shear Stress?

Fluid-induced shear stress occurs in every tissue in the body as a result of interstitial fluid movement. Tissue deformation by compression, tension or shear forces results in the movement of interstitial fluid around cells. Fluid movement acts as a transport vehicle for ions, proteins, carbohydrates and other molecules capable of movement within the matrix. As the fluid moves past cell membranes, a shear stress is generated. Applying stresses to cells in culture simulates the *in vivo* environment causing dramatic morphologic and biochemical responses.
FX-5000™ Tension System (FX-5000T)

Apply equibiaxial or uniaxial tension to cells in 2D or 3D culture.

- Computerized, vacuum-operated instrument that applies a defined controlled, static or variable duration cyclic tension to cells growing in vitro.
- Utilizes regulated vacuum to deform cells cultured on flexible-bottomed culture plates.
- Simulate in vivo tissue strains and frequencies in cells from muscle, lung, heart, blood vessels, skin, tendon, ligament, cartilage, and bone.
- Contains state-of-the-art digital valve to automatically regulate and maintain vacuum to provide the specified strain regimen.
- Multiple frequency, amplitude and waveform changes can be programmed in one regimen.
- Waveforms available: static, sinusoidal, heart stimulation, triangular, square, custom (Fig. 2).
- Supplied with cylindrical Loading Posts to provide equibiaxial strain, to be used with 6-well BioFlex® culture plates (page 17) for 2D cell constructs or with 6-well Tissue Train® Circular Foam culture plates (page 19) for 3D cell constructs.
- Optional Arctangle® Loading Posts to provide uniaxial strain, to be used with 6-well UniFlex™ culture plates (page 19).
- Optional Baseplate Kits (page 8) to use the FX-5000T with more than one Tension Baseplate, for Tissue Train® applications, for uniaxial strain, or for high-throughput tests.
- Drives up to four independent FlexLink® remote compression and/or tension controllers.
- Works with microscopy devices StageFlexer®, StageFlexer® Jr. (page 10), and FlexFlow™ (page 11).

FX-5000™ Tension System includes:
- Host computer with flat panel monitor
- FlexSoft FX-5000™ software
- FX5K™ Tension FlexLink®
- BioFlex® baseplate and four gaskets
- BioFlex® Loading Stations™ with 25 mm Loading Posts
- Four BioFlex® culture plates
- Drying filter, water trap, vacuum tubing, and grease/lubricant
FX-5000™ Tissue Train® System (FX-5000TT)

3D cell culture in a gel matrix with or without cyclic uniaxial tension.

- Stand-alone culture system to create 3D geometries for cell culture in a matrix gel or allows the cells to build a self-assembled matrix that connects to the anchors in a Tissue Train® culture plate (page 18).
- Utilizes regulated vacuum to deform cells cultured on flexible-bottomed culture plates.
- Simulate *in vivo* tissue strains and frequencies in various cells.
- Contains state-of-the-art digital valve to automatically regulate and maintain vacuum to provide the specified strain regimen.
- Multiple frequency, amplitude and waveform changes can be programmed in one regimen.
- Waveforms available: static, sinusoidal, heart stimulation, triangular, square, custom.
- Supplied with Arctangle® Loading Posts to provide uniaxial strain - using 6-well Tissue Train® culture plates (page 18) and 6-well UniFlex™ culture plates (page 19) - and with linear molds (Trough Loaders™) to create bioartificial tissue strips up to 35 mm length using Tissue Train® culture plates (Fig. 5). Further molds and plates for trapezoidal shaped hydrogel optionally available.
- Optional cylindrical Loading Posts to provide equibiaxial strain in 6-well BioFlex® culture plates (page 17) for 2D cell constructs or in 6-well Tissue Train® Circular Foam culture plates (page 19) for 3D cell constructs.
- Optional Baseplate Kits (page 8) to use the FX-5000TT with more than one baseplate, for Tension applications, or high throughput tests.
- Drives up to four independent FlexLink® remote compression and/or tension controllers.
- Works with microscopy devices StageFlexer®, StageFlexer® Jr. (page 10), FlexFlow™ (page 11), and image collection system ScanFlex™ (page 9).

**FX-5000™ Tissue Train® System includes:**
- Host computer with flat panel monitor
- FlexSoft FX-5000™ software
- FX5K™ Tension FlexLink®
- BioFlex® Baseplate and four gaskets
- Tissue Train® Trough Loaders™
- Arctangle® Loading Stations™
- Four Tissue Train® culture plates
- Drying filter, water trap, vacuum tubing, and grease/lubricant

![Figure 4. FX-5000™ Tissue Train® System](image)

![Figure 5. Bioartificial tissue development and uniaxial strain application with the Tissue Train® system](image)
FX-5000™ Compression System (FX-5000C)

Apply cyclic or static compression to cells in 3D culture.

- Computerized, pressure-operated instrument that applies a defined controlled, static or variable duration cyclic compression to cells growing in vitro.

- Utilizes regulated air pressure to deflect flexible-bottomed BioPress™ culture plates (page 21) compressing a tissue sample or 3D culture between a piston and a stationary platen (Fig. 8).

- Can apply up to 14 pounds of applied force.

- Simulate in vivo tissue forces and frequencies in cells from muscle, lung, heart, blood vessels, skin, tendon, ligament, cartilage, and bone.

- Contains state-of-the-art digital valve to automatically regulate and maintain pressure for a specified compression regimen.

- Multiple frequency, amplitude and waveform changes can be programmed in one regimen (Fig. 7).

- Waveforms available: static, sinusoidal, heart stimulation, triangular, square, custom.

- Drives up to four independent FlexLink® remote compression and/or tension controllers.

- Works with StagePresser™ microscopy device.

FX-5000™ Compression System includes:
- Host computer with flat panel monitor
- FlexSoft FX-5000™ software
- FX5K™ Compression FlexLink®
- Biopress™ Baseplate and four gaskets
- Compression clamping system
- Four BioPress™ culture plates
- Tubing and quick disconnects

→ Also see page 11 for StagePresser™ Microscopy Device (SP-3000), a single-well embodiment of the Compression apparatus.
**Flexcell® Transwell® Holder**

Holds Transwells® to allow for cell migration and co-culture assays to be performed in Flexcell® culture plates.

- Analyze cell migration in response to strain.
- Available for 6- and 24-well Flexcell® culture plates.
- Compatible with standard Transwell® sizes for 6-well and 24-well culture plates.

![Figure 9. 6-well Transwell® Holder.](image)

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**Flex Jr. Tension System**

Apply equibiaxial or uniaxial tension to cells in *microscopy devices*.

- Computerized, vacuum-operated system that applies a defined controlled, static or variable duration cyclic tension to cells in Flexcell® microscopy tension devices* (pp. 10 - 11): 
  - StageFlexer®, StageFlexer® Jr., and FlexFlow™
- Utilizes regulated vacuum to deform flexible membranes in microscopy devices*.
- Simulate in vivo tissue strains and frequencies in cells from muscle, lung, heart, blood vessels, skin, tendon, ligament, cartilage, and bone.
- Contains state-of-the-art digital valve to automatically regulate and maintain vacuum for a specified strain regimen.
- Multiple frequency, amplitude and waveform changes can be programmed in one regimen.
- Waveforms available: static, sinusoidal, heart stimulation, triangular, square, custom
- Not compatible with Flexcell’s® Baseplate Kits or Flexcell’s® culture plates.

![Figure 11. Flex Jr. Tension System](image)

Flex Jr. Tension System includes:
- Host computer with flat panel monitor
- FlexSoft® Flex Jr. software
- Flex Jr. Tension FlexLink®

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Transwell® is a registered trademark of Corning® Inc.
FlexLink® for Tension or Compression (FX-5000TFL or FX-5000CFL)

Run multiple regimens at one time!

- Upgrade your existing FX-5000T or FX-5000C with a second controller that links with an FX-5000™ system computer allowing the user to simultaneously operate two different regimens on two different baseplates. *(May require an additional vacuum pump or compressor depending on the intensity of the regimens!)*
- Expand the application area of your FX-5000T system with the possibility to apply Compression tests by adding a Compression FlexLink® FX-5000CFL. *(Requires also a compressor!)*
- Expand the application area of your FX-5000C system with the possibility to apply Tension tests by adding a Tension FlexLink® FX-5000TFL. *(Requires also a vacuum pump!)*
- Connects in a series to operate up to four FlexLinks® from a central computer.

Flexcell® Baseplate Kits

Expand the application areas of your Tension or Tissue Train® System.

- BioFlex® Baseplate Kit (BFBK-4000)
  - Apply equibiaxial strain to cells cultured in monolayer in the BioFlex® culture plates (page 17) or to 3D constructs in the Tissue Train® Circular Foam culture plates (page 19).
  - Available with 25 mm, 28 mm, or 31 mm diameter cylindrical Loading Stations™.
- Tissue Train® Baseplate Kit (TTBK-4000) for creating 3D tissues
  - Create 3D cell constructs on Tissue Train® culture plates (page 18) using Trough Loaders™ (molds).
  - Apply uniaxial strain to cells cultured on Tissue Train® or cultured on UniFlex culture plates (page 19) with the supplied Arctangle® Loading Stations™.
- UniFlex® Baseplate Kit (UFBK-4000)
  - Apply uniaxial strain to cells cultured in monolayer on the membrane of the UniFlex® culture plates (page 19).
- 24-Well HT Baseplate Kit (HTBK-4000)
  - High throughput strain tests of cells cultured in Flexcell’s® 24-well HT BioFlex® culture plates (pg 17).
  - Kit includes Cell Seeders™ to place cells in the central region of the wells.

Please see pages 22 and 23 for further information on the components of the Baseplate Kits.
ScanFlex™ Scanning Device

Automated scanning device with area measurement software.

- Can be used in conjunction with the Tissue Train® System to determine the compaction kinetics (change in area) of 3D cell seeded-gels.
- Scans four 6-well or 24-well Flexcell® culture plates placed on the scanner bed.
- Measure gel compaction in 3D bioartificial tissues.
- Automated repetitive scanning process.
- Scans and saves images up to 600 dpi of 3D tissue constructs.
- User defined frequency and time intervals of image capture.
- Images can be imported into XyFlex™ programme (Fig. 16) to analyze area measurement in a series of images.

- XyFlex™ software evaluates the area compaction of 3D bioartificial tissue constructs.
- The software is compatible with images captured with the ScanFlex™ system.
- XyFlex™ creates Microsoft® Excel and text files for evaluation of changes in area.
- XyFlex™ includes a manual editing tool for customized image processing.
- XyFlex™ allows image grouping for ease of post-process analysis.

- ScanFlex™ system includes:
  - ScanFlex™ and XyFlex™ software
  - Epson® colour scanner
  - Frames for 6-well and 24-well Flexcell® culture plates
  - Scanner plate cover
  - Instruction manual

Figure 14. ScanFlex™ scanning device

Figure 15. Arrangement of Flexcell®’s A) 24-well and B) 6-well culture plates on the scanner bed

Figure 16. XyFlex™ software
StageFlexer® Microscopy Device (SF-3000)

A single-well embodiment of a BioFlex® culture plate well.

- Designed to strain cells in monolayer while observing the cellular activity with an **upright microscope** in real-time.
- Device can be used with FX-5000™ Tension, FX-5000™ Tissue Train® System, and Flex Jr. Tension System that allow the control of strain frequency, amplitude, waveform, and cycles (or time period).
- StageFlexer® consists of a single 35 mm well.
- Membranes (page 20) are deformed across a cylindrical Loading Post (equibiaxial strain).
- StageFlexer® Microscopy Devices includes:
  - StageFlexer® device
  - Three cylindrical Loading Posts (25 mm, 28 mm, and 31 mm)
    used to vary strain magnitudes
  - Gaskets, o-ring, snap ring, and pliers
  - Silicone-based lubricant
  - Six StageFlexer® membranes

StageFlexer® Jr. Microscopy Device (SF-4000)

Microscopy device for membranes removed from Flexcell® culture plates.

- Designed to strain cells in monolayer while observing the cellular activity with an **upright microscope** in real-time.
- Device can be used with FX-5000™ Tension, FX-5000™ Tissue Train® System, and Flex Jr. Tension System that allow the control of strain frequency, amplitude, waveform, and cycles (or time period).
- StageFlexer® Jr. consists of a single 1-inch well designed to accept membranes removed from BioFlex®, UniFlex® or Tissue Train® culture plates.
- Continue to strain cells while observing responses in real-time on a microscope stage.
- Membranes can be deformed across a cylindrical Loading Post (equibiaxial strain) or across an Arctangle® Loading Post (uniaxial strain).
- StageFlexer® Jr. Microscopy Device includes:
  - StageFlexer® Jr. device
  - One 18.5 mm diameter cylindrical Loading Post
  - One Arctangle® Loading Post
  - Gaskets, O-ring, snap ring and pliers
  - Silicone-based lubricant
StagePresser™ Microscopy Device (SP-3000)

A single-well embodiment of the Compression apparatus.

- Designed to compress a single tissue sample or cells in 3D culture while viewing the cellular activity under a microscope.
- Works with the FX-5000™ Compression system.
- View compressed cells in real-time with an **upright microscope**.
- Piston and stationary platen compress samples on StagePresser™ membranes (page 21).

- StagePresser™ includes:
  - StagePresser™ device
  - Three acrylic pistons and platen-loaded StagePresser™ membranes

→ Also see page 6 for FX-5000™ Compression System (FX-5000C).

FlexFlow™ Shear Stress Device (FF-3000)

*Flex your cells while applying a shear stress.*

- Parallel plate laminar flow device designed to apply fluid shear stress and/or cyclic strain to cells in culture while providing a means for viewing cell activity under an **upright microscope** in real-time.
- Culture cells on matrix bonded rubber surfaces using StageFlexer® membranes (page 20) or on matrix treated glass Culture Slips® (page 21).
- Strain cells using the FX-5000™ Tension, Flex Jr. Tension, or Tissue Train® system before, during or after applying shear stress.
- Uses a computer controlled peristaltic pump to regulate shear stress from 0 - 35 dynes/cm².

- FlexFlow™ System includes:
  - FlexFlow™ device
  - Tubing and quick disconnects
  - Peristaltic pump
  - StreamSoft™ software
  - Two pulse dampeners
Apply fluid shear stress to cells with laminar, pulsatile, or oscillating flow

- Parallel-plate flow system used to apply fluid-induced shear stress to cells grown in a monolayer.
- Includes a six-chamber laminar flow device and can be used to apply laminar, pulsatile*, or oscillating* flow to cells cultured on special matrix coated PTFE rimmed 25 × 75 × 1 mm Culture Slips® (page 21).
- Regulation of shear stress from 0 - 35 dynes/cm² by computer-controlled peristaltic pump.
- Analyze effects of fluid flow on cell alignment, mRNA and protein expression, and signaling pathways.
- Remove quick disconnect fittings for easy cleaning after use.
- Streamer® device is autoclavable.
- Run up to six slides at one time.
- Comes with two pulse dampeners.

- Streamer® System includes:
  - Streamer® device
  - Notebook computer
  - Tubing and quick disconnects
  - Peristaltic pump
  - StreamSoft™ software
  - Two pulse dampeners
  - 12 Culture Slips®

*In order to apply pulsatile or oscillating flow the Osci-Flow® (page 13) is required. Osci-Flow® needs to be ordered separately in addition to the Streamer® System.
Osci-Flow® Flow Controller (STR-4000-OFS)

The ultimate in fluid flow direction control!

- Provides regulated oscillatory and pulsatile flow control via computer controlled action.
- Minimizes flow response lag by eliminating inertial effects of decelerating and accelerating pumps and motors.
- Reverses fluid flow instantaneously.
- Works with Streamer® and FlexFlow™ shear stress devices.
- Adapts to other perfusion systems.
- Accomodates any MasterFlex L/S series or comparable tubing.
- Interfaces with most laptops via USB.

- Osci-Flow® System includes:
  - Osci-Flow® device
  - Tubing and quick disconnects
  - StreamSoft™ software

Figure 27. Osci-Flow® Controller

Figure 28. Set-up of the Streamer® device with Osci-Flow®

Do you require further information on the Flexcell® equipment?

We would be pleased to send you further information including our Flexcell® CD with videos or to contact you by phone for personal advice concerning all the Flexcell® products.

Contact us by e-mail info@dunnlab.de or by phone +49 (0) 26 83 / 4 30 94.
If you send us your phone number and a suitable time, we would also be pleased to call you!
Flexcell’s® Culture Plates

- Rigorously tested and guaranteed to be of the highest quality matrix-coated or untreated silicone elastomer or polystyrene culture plates.
- Well characterized elastomer properties.
- Equibiaxial or uniaxial strain applications.
- Strain applications simulating \textit{in vivo} strains.
- Achieve a more natural environment \textit{in vitro}.
- Gamma sterilization assures a sterile growth surface.

Matrix-Bonded and Charged Culture Plate Growth Surfaces

Flexcell’s® unique culture plates provide researchers with matrix bonded growth surfaces that promote attachment and growth of a variety of cell types. Matrix coatings, such as type I collagen peptides, elastin, fibronectin (as RGD repeat peptides), and laminin (as YIGSR peptides), enhance attachment of specific cell types. These specialty growth surfaces help to better simulate the \textit{in vivo} environment.

Flexcell® culture plates including BioFlex®, Tissue Train®, UniFlex® series culture plates, StageFlexer® membranes and Culture Slips® are available with the following treatments and also as untreated versions:

- Amino
- Collagen Type I
- Collagen Type IV
- Elastin
- ProNectin
- Laminin

\textbf{NOTE:} See the integrin table on the following page to match your cell’s integrin panel with the appropriate growth surface.

Flexcell’s® culture plates are stringently tested to assure the highest quality control and the best cell attachment and growth possible. Attachment factors are covalently bonded to the culture plate rubber membranes or plastics using our proprietary methods that result in optimal cell adherence and clarity for viewing cells. Culture plates are sterilized with gamma radiation and have a shelf life of one year.

The Flexcell® Tension System provides a strain component for dynamically culturing cells \textit{in vitro}. Researchers use the Flexcell® culture plates together with the tension system to apply a defined, controlled, static or variable duration cyclic tension to cells.

The Flexcell® Streamer® applies fluid flow to cells in culture. Researchers use Culture Slips® together with the flow system to apply a controlled laminar, oscillatory, or pulsatile flow to cells.

Flexcell’s® culture plates together with Flexcell’s® systems for applying mechanical load provide the investigator with the ability to grow cells \textit{in vitro} in a manner that better simulates an \textit{in vivo} environment.
Matrix-Bonded Growth Surfaces

Flexcell® culture plates are available with the following treatments:

**Genetic type I collagen** for improved attachment and adherence of cells including:
- Continuous cell lines
- Primary cells
- Osteoblasts
- Chondrocytes
- Tendon fibroblasts
- Aortic, venous, and capillary endothelial cells
- Lung type II epithelial cells
- Ligament fibroblasts
- Smooth, striated and cardiac
- Myoblasts
- Myocytes

**Fibronectin, as RGD repeat peptides, and ProNectin F** for the improved attachment of cells including:
- Fibroblasts
- Embryonic cells

**Laminin, as YIGSR peptides, for the improved attachment of cells including:**
- Glial cells
- Neurons
- Cells grown on type I collagen or ProNectin F
- Astrocytes

**Positively charged amino hydrophilic** for the improved attachment of cells including:
- Endothelial cells
- Smooth muscle cells

**Elastin** for the improved attachment of cells including:
- Endothelial cells
- Smooth muscle cells

* See the integrin table below to match your cell’s integrin panel with the appropriate growth surface.

### Vertebrate Integrins Grouped in Subfamilies Sharing a Common β Subunit

<table>
<thead>
<tr>
<th>Subunits</th>
<th>Ligands Sequenced</th>
<th>Minimal Sequence of Integrin Binding Site*</th>
</tr>
</thead>
<tbody>
<tr>
<td>β₁⁺</td>
<td>α₁</td>
<td>Collagen, Laminin</td>
</tr>
<tr>
<td></td>
<td>α₂</td>
<td>Collagen, Laminin</td>
</tr>
<tr>
<td></td>
<td>α₃</td>
<td>Fibronectin, Laminin, Collagen</td>
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<td></td>
<td>α₄</td>
<td>Fibronectin, VCAM-1</td>
</tr>
<tr>
<td></td>
<td>α₅</td>
<td>Fibronectin</td>
</tr>
<tr>
<td></td>
<td>α₆⁺</td>
<td>Laminin</td>
</tr>
<tr>
<td></td>
<td>α₇</td>
<td>Laminin</td>
</tr>
<tr>
<td></td>
<td>α₈</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>αᵥ</td>
<td>Vitronectin, Fibronectin</td>
</tr>
<tr>
<td>β₂</td>
<td>αᵢ₁</td>
<td>ICAM-1, ICAM-2</td>
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<tr>
<td></td>
<td>αᵢ₉</td>
<td>C3b component of complement (inactivated), Fibronectin, Factor X, ICAM-1</td>
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<tr>
<td></td>
<td>αₓ</td>
<td>Fibronectin, C3b component of complement</td>
</tr>
<tr>
<td>β₃⁺</td>
<td>αᵢ₁₈</td>
<td>Fibronectin, ProNectin F, von Willebrand factor, Vitronectin, Thrombospondin</td>
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<td></td>
<td>αᵥ</td>
<td>Vitronectin, Fibronectin, von Willebrand factor, Thrombospondin, Fibronectin, Osteopontin, Collagen</td>
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<td>β₄⁺</td>
<td>α₈⁺</td>
<td>Laminin</td>
</tr>
<tr>
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<td>αᵥ</td>
<td>Vitronectin</td>
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<td>β₇</td>
<td>α₄</td>
<td>Fibronectin, VCAM-1</td>
</tr>
<tr>
<td></td>
<td>αᵢₑ</td>
<td>?</td>
</tr>
<tr>
<td>When using the following culture plates</td>
<td>Required Loading Stations</td>
<td>Plates usable with the following systems if upgraded with the listed accessories</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| BioFlex® 6-well culture plates (page 17) | BioFlex® Loading Stations™ | FX-4000T and FX-5000T require no further equipment  
FX-4000TT and FX-5000TT require BioFlex® Baseplate Kit or optional separately available BioFlex® Loading Stations™  
FX-5000C requires Tension FlexLink® with BioFlex® Baseplate and vacuum pump |
| BioPress™ 6-well Compression culture plates (page 21) | Not required | FX-5000T requires Compression FlexLink® with Compression Baseplate and compressor  
FX-5000TT requires Compression FlexLink® with Compression Baseplate and compressor  
FX-4000C and FX-5000C require no further equipment |
| HT BioFlex® 24-well culture plates (page 17) | 24-well Loading Stations™ | FX-4000T and FX-5000T require 24-well HT Baseplate Kit  
FX-4000TT and FX-5000TT require 24-well HT Baseplate Kit  
FX-5000C requires Tension FlexLink®, vacuum pump and 24-well HT Baseplate Kit |
| Tissue Train® 6-well culture plates (page 18) | Arctangle® Loading Stations™, Trough Loaders™ | FX-4000T and FX-5000T require Tissue Train® Baseplate Kit or optional separately available Arctangle® Loading Stations™ and Trough Loaders™  
FX-4000TT and FX-5000TT require no further equipment  
FX-5000C requires Tension FlexLink®, vacuum pump and Tissue Train® Baseplate Kit, or Tension FlexLink®, vacuum pump and optional separately available Arctangle® Loading Stations™ and Trough Loaders™ |
| Tissue Train® Circular Foam 6-well culture plates (page 19) | BioFlex® Loading Stations™ | FX-4000T and FX-5000T require no further equipment  
FX-4000TT and FX-5000TT require BioFlex® Baseplate Kit or optional separately available BioFlex® Loading Stations™  
FX-5000C requires Tension FlexLink® and vacuum pump |
| Tissue Train® Trapezoidal 6-well culture plates (page 18) | Arctangle® Loading Stations™, Trapezoidal Trough Loaders™ | FX-4000T and FX-5000T require Tissue Train® Baseplate Kit and Trapezoidal Trough Loaders™ or optional separately available Arctangle® Loading Stations™ and Trapezoidal Trough Loaders™  
FX-4000TT and FX-5000TT require Trapezoidal Trough Loaders™  
FX-5000C requires Tension FlexLink®, vacuum pump, Tissue Train® Baseplate Kit and Trapezoidal Trough Loaders™; or Tension FlexLink®, vacuum pump, optional separately available Arctangle® Loading Stations™ and Trapezoidal Trough Loaders™ |
| UniFlex® 6-well culture plates (page 19) | Arctangle® Loading Stations™ | FX-4000T and FX-5000T require Tissue Train® Baseplate Kit or optional separately available Arctangle® Loading Stations™  
FX-4000TT and FX-5000TT require no further equipment  
FX-5000C requires Tension FlexLink®, vacuum pump and Tissue Train® Baseplate Kit; or Tension FlexLink®, vacuum pump and optional separately available Arctangle® Loading Stations™ |
**6-well BioFlex® Culture Plates**

Flexible bottomed culture plate used with BioFlex® Loading Stations™ for providing equibiaxial strain to cells in monolayer culture.

- Flexible silicone elastomer membrane.
- 6-well culture plate with total growth surface area of 57.75 cm² (9.62 cm²/well).
- Optically clear for direct viewing of cells with inverted or upright microscopes (membrane thickness: 0.020 inch/0.508 mm).
- Covalently bonded surfaces: Amino, Collagen (Type I or IV), Elastin, ProNectin (RGD), Laminin (YIGSR).
- Low autofluorescence for use in immunohistochemical assays or with fluorescent probes.
- Provides uniform radial and circumferential strains when used with cylindrical BioFlex® Loading Stations™.
- Available in cases of 10 and 40 plates.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF-3001U</td>
<td>BioFlex® Culture Plate – Untreated</td>
</tr>
<tr>
<td>BF-3001A</td>
<td>BioFlex® Culture Plate – Amino</td>
</tr>
<tr>
<td>BF-3001C</td>
<td>BioFlex® Culture Plate – Collagen Type I</td>
</tr>
<tr>
<td>BF-3001C/IV</td>
<td>BioFlex® Culture Plate – Collagen Type IV</td>
</tr>
<tr>
<td>BF-3001E</td>
<td>BioFlex® Culture Plate – Elastin</td>
</tr>
<tr>
<td>BF-3001P</td>
<td>BioFlex® Culture Plate – ProNectin</td>
</tr>
<tr>
<td>BF-3001L</td>
<td>BioFlex® Culture Plate – Laminin</td>
</tr>
</tbody>
</table>

See page 22 for detailed information on the BioFlex® Loading Stations.

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**24-well HT BioFlex® Culture Plates**

High throughput flexible silicone elastomer bottomed culture plates to be used only with the 24-well HT Baseplate Kit (page 8).

- Microplate reader compatible size and a total growth surface area of 37.47 cm² (1.56 cm²/well).
- Optically clear for direct viewing of cells with inverted or upright microscopes (membrane thickness: 0.254 mm).
- Apply up to 8 % equibiaxial strain to cells in monolayer culture with Flexcell® Tension system and 24-well Loading Stations™.
- Covalently bonded surfaces: Amino, Collagen (Type I or IV), Elastin, ProNectin (RGD), Laminin (YIGSR).
- Available with black or white frame in cases of 10 and 40 plates.
- Please note: the use of the HT BioFlex® culture plates with the Flexcell FX-4000™ and FX-5000™ Tension and Tissue Train® systems requires the 24-well HT Baseplate Kit (page 8) and may need a software update.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Cat. No.</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>HTPB-3001U</td>
<td>HTPW-3001U</td>
<td>HT BioFlex® Culture Plate – Untreated</td>
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<tr>
<td>HTPB-3001A</td>
<td>HTPW-3001A</td>
<td>HT BioFlex® Culture Plate – Amino</td>
</tr>
<tr>
<td>HTPB-3001C</td>
<td>HTPW-3001C</td>
<td>HT BioFlex® Culture Plate – Collagen Type I</td>
</tr>
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<td>HTPB-3001C/IV</td>
<td>HTPW-3001C/IV</td>
<td>HT BioFlex® Culture Plate – Collagen Type IV</td>
</tr>
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<td>HTPB-3001E</td>
<td>HTPW-3001E</td>
<td>HT BioFlex® Culture Plate – Elastin</td>
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<td>HTPB-3001P</td>
<td>HTPW-3001P</td>
<td>HT BioFlex® Culture Plate – ProNectin</td>
</tr>
<tr>
<td>HTPB-3001L</td>
<td>HTPW-3001L</td>
<td>HT BioFlex® Culture Plate – Laminin</td>
</tr>
</tbody>
</table>
6-well Tissue Train® Culture Plates

Flexible bottomed culture plate used with Arctangle® Loading Stations™ and Trough Loaders™ to apply uniaxial strain to 3D cell-seeded gel constructs.

- Create 3D cell-seeded constructs on a Tissue Train® plate using a Trough Loader™ (Fig. 32) or a Trapezoidal Trough Loader™ as a mold (Trough Loaders™ not included with the plates).
- Tissue Train® Plates available with either CEREX® (a non-woven nylon mesh) or foam (open-cell porous) anchor stems. Anchor material has not been found to affect the compaction kinetics of the collagen gel. However, the foam anchor stems allow for increased construct survival time as measured by time to construct failure/detachment from the anchors.
- Apply a load regimen of uniaxial cyclic strain to the cellular construct using a Flexcell Tension system and Arctangle® Loading Stations™.
- Observe cell responses in 3D matrix with phase contrast, fluorescence or scanning confocal microscopy.
- Covalently bonded anchors: Amino, Collagen (Type I or IV), Elastin, ProNectin (RGD), Laminin (YIGSR).
- Available in cases of 10 and 40 plates.

For use with (linear) Trough Loaders™

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Cat. No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEREX®</td>
<td>Foam</td>
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<tr>
<td>TT-4001U</td>
<td>TT-5001U</td>
<td>Tissue Train® Culture Plate – Untreated</td>
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<tr>
<td>TT-4001A</td>
<td>TT-5001A</td>
<td>Tissue Train® Culture Plate – Amino</td>
</tr>
<tr>
<td>TT-4001C</td>
<td>TT-5001C</td>
<td>Tissue Train® Culture Plate – Collagen Type I</td>
</tr>
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<td>TT-4001C/IV</td>
<td>TT-5001C/IV</td>
<td>Tissue Train® Culture Plate – Collagen Type IV</td>
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<td>TT-4001E</td>
<td>TT-5001E</td>
<td>Tissue Train® Culture Plate – Elastin</td>
</tr>
<tr>
<td>TT-4001P</td>
<td>TT-5001P</td>
<td>Tissue Train® Culture Plate – ProNectin</td>
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<tr>
<td>TT-4001L</td>
<td>TT-5001L</td>
<td>Tissue Train® Culture Plate – Laminin</td>
</tr>
</tbody>
</table>

For use with Trapezoidal Trough Loaders™

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Cat. No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEREX®</td>
<td>Foam</td>
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<tr>
<td>TTTP-4001U</td>
<td>TTTP-5001U</td>
<td>Trapezoidal TT® Culture Plate – Untreated</td>
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<tr>
<td>TTTP-4001A</td>
<td>TTTP-5001A</td>
<td>Trapezoidal TT® Culture Plate – Amino</td>
</tr>
<tr>
<td>TTTP-4001C</td>
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<td>Trapezoidal TT® Culture Plate – Collagen Type IV</td>
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<td>TTTP-4001E</td>
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<td>Trapezoidal TT® Culture Plate – Elastin</td>
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<td>TTTP-5001P</td>
<td>Trapezoidal TT® Culture Plate – ProNectin</td>
</tr>
<tr>
<td>TTTP-4001L</td>
<td>TTTP-5001L</td>
<td>Trapezoidal TT® Culture Plate – Laminin</td>
</tr>
</tbody>
</table>
6-well Tissue Train® Circular Foam Culture Plates

Flexible bottomed culture plate used with BioFlex® Loading Stations™ for providing biaxial strain to circular 3D cell-seeded gel constructs.

- Create circular 3D cell-seeded gel constructs (no Trough Loader™ required).
- Apply a load regimen of biaxial cyclic strain to the cellular construct using a Tension or Tissue Train® system with cylindrical Loading Stations™.
- Matrix-bonded foam circular anchor for improved cell attachment.
- Observe cell responses in 3D matrix with phase contrast, fluorescence or scanning confocal microscopy.
- Monitor changes in cell shape, tissue organization, cell migration, division, gene expression, protein expression and secretion.
- Covalently bonded anchors: Amino, Collagen (Type I or IV), Elastin, ProNectin (RGD), Laminin (YIGSR).
- Available in cases of 10 and 40 plates.

<table>
<thead>
<tr>
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<th>Description</th>
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<td>Circular Foam Culture Plate – Untreated</td>
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<td>TTCF-5001A</td>
<td>Circular Foam Culture Plate – Amino</td>
</tr>
<tr>
<td>TTCF-5001C</td>
<td>Circular Foam Culture Plate – Collagen Type I</td>
</tr>
<tr>
<td>TTCF-5001C/IV</td>
<td>Circular Foam Culture Plate – Collagen Type IV</td>
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<tr>
<td>TTCF-5001E</td>
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</tr>
<tr>
<td>TTCF-5001P</td>
<td>Circular Foam Culture Plate – ProNectin</td>
</tr>
<tr>
<td>TTCF-5001L</td>
<td>Circular Foam Culture Plate – Laminin</td>
</tr>
</tbody>
</table>

Please note that the cat. no. for these plates have changed.

6-well UniFlex® Culture Plates

Flexible bottomed culture plate used with Arctangle® Loading Stations™ to provide uniaxial strain to cells in monolayer culture.

- Compatible with the Flexcell® Tension and Tissue Train® systems.
- Relationship of strain to vacuum well characterized.
- Strain field represented by a 0.6” wide x 0.952” (3.68 cm²) long centrally located rectangular region (Fig. 33).
- Uniaxial strain varies by only +/- 1.5 % across the designated uniaxial strain region.
- Covalently bonded surfaces: Amino, Collagen (Type I or IV) Elastin, ProNectin (RGD), Laminin (YIGSR).
- Available in cases of 10 and 40 plates.

* Arctangle® Loading Stations™ required for correct application of uniaxial strain.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Description</th>
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</thead>
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<td>UF-4001U</td>
<td>UniFlex® Culture Plate – Untreated</td>
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<tr>
<td>UF-4001A</td>
<td>UniFlex® Culture Plate – Amino</td>
</tr>
<tr>
<td>UF-4001C</td>
<td>UniFlex® Culture Plate – Collagen Type I</td>
</tr>
<tr>
<td>UF-4001C/IV</td>
<td>UniFlex® Culture Plate – Collagen Type IV</td>
</tr>
<tr>
<td>UF-4001E</td>
<td>UniFlex® Culture Plate – Elastin</td>
</tr>
<tr>
<td>UF-4001P</td>
<td>UniFlex® Culture Plate – ProNectin</td>
</tr>
<tr>
<td>UF-4001L</td>
<td>UniFlex® Culture Plate – Laminin</td>
</tr>
</tbody>
</table>

Figure 31. UniFlex® culture plate with schematic of the strain region
FlexStop™ (BFS-3000)

Be Selective! Use a FlexStop™ to block stretching.

- Reusable valved rubber stopper that inserts into the underside of a BioFlex® culture plate well to prevent vacuum-induced deformation (Fig. 34).
- Provides a convenient negative control when testing mechanical load effects on cells in the same BioFlex® culture plate.
- Designed to work in conjunction with the BioFlex® culture plates and BioFlex® Loading Stations™.
- Also works with Tissue Train® and UniFlex® culture plates.

FlexStop™ includes:
- Twelve rubber stoppers
- Twelve brass pins

![Figure 32. Schematic of strain inhibition with the use of a FlexStop™ on the underside of a BioFlex® culture plate well](image)

StageFlexer® Membranes

Flexible growth surface for the StageFlexer® and FlexFlow™ devices.

- Individually packaged 43 mm silicone rubber membranes (come in sterile culture dishes).
- Clear for direct viewing of cells optically.
- Viscoelastic under mechanical loading.
- Same growth surfaces as the BioFlex® culture plates.
- Covalently bonded surfaces: Amino, Collagen (Type I or IV), Elastin, ProNectin (RGD), Laminin (YIGSR).
- Available in cases of 6 and 36 membranes.

<table>
<thead>
<tr>
<th>Cat. No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFM-U</td>
<td>StageFlexer® Membrane – Untreated</td>
</tr>
<tr>
<td>SFM-A</td>
<td>StageFlexer® Membrane – Amino</td>
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<tr>
<td>SFM-C</td>
<td>StageFlexer® Membrane – Collagen Type I</td>
</tr>
<tr>
<td>SFM-C/IV</td>
<td>StageFlexer® Membrane – Collagen Type IV</td>
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<tr>
<td>SFM-E</td>
<td>StageFlexer® Membrane – Elastin</td>
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<tr>
<td>SFM-P</td>
<td>StageFlexer® Membrane – ProNectin</td>
</tr>
<tr>
<td>SFM-L</td>
<td>StageFlexer® Membrane – Laminin</td>
</tr>
</tbody>
</table>
6-well BioPress™ Culture Plates (BF-3000C)

Culture plate for use with the Flexcell® Compression system.

- Each well contains an acrylic piston used with a stationary platen (supplied with the Compression system, not included with the plates) to deform 3D tissue samples or cell seeded constructs using the FX-5000™ Compression system.
- Ring foam holders keep samples confined to central region of each well.
- All plates come pre-sterilized.
- Available in cases of 10 or 40 plates.

![Figure 33. BioPress™ culture plate with acrylic pistons adhered to the silicone elastomer well bottom, foam sample holders (far left), and stationary platens (left of plate)](image)

StagePresser™ Membranes (SPM-3000)

Flexible growth surface for use with the StagePresser™ device.

- Each membrane contains an acrylic piston which is compressed against a stationary platen on the StagePresser™ device to deform 3D tissue samples or cell-seeded constructs.
- Ring foam holders keep samples confined to central region of each membrane.
- Each membrane comes individually packaged in a sterile cell culture dish.
- Available in cases of 6 membranes with piston and foam retainer.

![Figure 33. StagePresser™ membrane with acrylic piston and foam sample holder](image)

Culture Slips®

Surface treated slides for use with Streamer® and FlexFlow™.

- Available in two sizes:
  - 75 x 25 x 1.0 mm (for Streamer® or FlexFlow™), 75 x 24 x 0.2 mm (for FlexFlow™ only).
  - 75 x 25 x 1.0 mm Culture Slips® are rimmed with a 1.0 mm wide PTFE border to help limit cell culture growth to the portion of the slip exposed to fluid flow.
- Low autofluorescence.
- Matrix-treated to promote cell attachment.
- Covalently bonded surfaces: Amino, Collagen (Type I or IV) Elastin, ProNectin (RGD), Laminin (YIGSR).
- Delivered in sterile twin packs for one time immediate use.
- Available in cases of 6 and 36 culture slips.

<table>
<thead>
<tr>
<th>75 x 25 x 1.0 mm for Streamer® or FlexFlow™</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat. No.</td>
<td>Description</td>
</tr>
<tr>
<td>CS-U</td>
<td>Culture Slips® – Untreated</td>
</tr>
<tr>
<td>CS-A</td>
<td>Culture Slips® – Amino</td>
</tr>
<tr>
<td>CS-C</td>
<td>Culture Slips® – Collagen Type I</td>
</tr>
<tr>
<td>CS-C/IV</td>
<td>Culture Slips® – Collagen Type IV</td>
</tr>
<tr>
<td>CS-E</td>
<td>Culture Slips® – Elastin</td>
</tr>
<tr>
<td>CS-P</td>
<td>Culture Slips® – ProNectin</td>
</tr>
<tr>
<td>CS-L</td>
<td>Culture Slips® – Laminin</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>75 x 24 x 0.2 mm for FlexFlow™</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cat. No.</td>
<td>Description</td>
</tr>
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<td>Culture Slips® – Untreated</td>
</tr>
<tr>
<td>FFCS-A</td>
<td>Culture Slips® – Amino</td>
</tr>
<tr>
<td>FFCS-C</td>
<td>Culture Slips® – Collagen Type I</td>
</tr>
<tr>
<td>FFCS-C/IV</td>
<td>Culture Slips® – Collagen Type IV</td>
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<tr>
<td>FFCS-E</td>
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<td>FFCS-P</td>
<td>Culture Slips® – ProNectin</td>
</tr>
<tr>
<td>FFCS-L</td>
<td>Culture Slips® – Laminin</td>
</tr>
</tbody>
</table>
Principle of Loading Stations™ and Equibiaxial Strain

BioFlex® Loading Stations™ provide uniform radial and circumferential strains to cells cultured on flexible membranes. Loading Stations™ are designed for use with BioFlex®, flexible-bottomed culture plates and the Flexcell® Tension system to provide regulated strain to cultured cells. The Loading Stations™ are comprised of a 3.3” x 5” Lexan® plate and six removable Delrin® planar faced cylinders or posts (Fig. 34). The posts are positioned on the Lexan® plate such that each is centered beneath the rubber membrane of each well of a 35 mm BioFlex® culture plate (Fig. 35). When vacuum is applied to a BioFlex® culture plate* with a Flexcell® Tension System, the membrane deforms across the post face creating uniform equibiaxial strain (Fig. 35).

Figure 34. BioFlex® baseplate showing the Loading Stations™ with six loading posts (P) and BioFlex® culture plates in red rubber gaskets

Figure 35. Schematic of the BioFlex® membrane deformed across a loading post.

Loading posts are available in three standard diameters: 25, 28, and 31 mm. Use of loading posts provides: 1) constrained distension to the flexible membrane, and 2) nominal fluid shear stress because the medium is not moving up and down over the field. A silicone-based lubricant is used to minimize friction between the membrane and post.

Please note: Flexcell® ships the 25 mm Loading Stations™ as standard with the FX-5000™ Tension system unless the 28 mm or 31 mm Loading Stations™ are requested upon ordering.

24-well High Throughput Plates. The 24-well HT BioFlex® plate (Fig. 36) is designed with a flexible silicone membrane well bottom and with standard industry perimeter dimensions. The standard size allows the plate to be utilized with plate readers and other standard culture plate devices. The total growth surface area for these plates is 37.47 cm² (or 1.56 cm²/well). The 24-well Loading Stations™ have 10 mm diameter loading posts made of polystyrene. Equibiaxial strain is applied in the same manner as depicted in Figure 35.

Figure 36. 24-Well HT BioFlex® culture plate

* Flexcell culture plates are good for 1 year when stored at room temperature in the dark or out of direct light.

→ Please see page 4 for further information on the Tension system.
Principle of Loading Stations™ Expanded to Uniaxial Strain

3D Tissue Constructs with Tissue Train®.
The above concept of strain application has been expanded to enable uniaxial strain to both 3D tissue cultures and monolayer cell cultures. Uniaxial strain is achieved through selectively controlling the portion of the flexible membrane that is exposed to the regulated vacuum. This is achieved through the use of special designed Arctangle® Loading Stations™ (Fig. 37). In addition to the Arctangle® Loading Stations™, specially configured culture plates are required to facilitate the uniaxial strain to the cell or tissue cultures. Tissue Train® culture plates are used in combination with Arctangle® Loading Stations™ (Fig. 38) to achieve uniaxial strain in a 3-dimensional tissue construct. Please note that the Trough Loader™ also shown in Figure 40 is used to develop three-dimensional tissue constructs.

Monolayer Cell Cultures with UniFlex®.
Uniaxial strain is achieved in monolayer cell cultures through the combined use of UniFlex® culture plates and Arctangle® Loading Stations™ (Fig. 39 and 40). UniFlex® culture plates are 35 mm 6-well culture plates with the same overall dimensional configuration as the BioFlex® and Tissue Train® culture plates. Uniaxial strain is achieved on a centrally located rectangular portion of the UniFlex® well (Fig. 41). The dimensions of this region are 15.25 mm x 24.18 mm (0.600" x 0.952"). The uniaxial strain orientation is along the 24.18 mm axis. This region provides a total uniaxial strain area of 3.68 cm² (0.57 in²).

Figure 37. Arctangle® Loading Stations™

Figure 38. Tissue Train® culture plate from 3D culture of cell-matrix constructs. The top left well has a Trough Loader™ beneath the flexible membrane. The 4 adjacent wells show the anchors for attachment of cells and gel from an uniaxial, linear construct. The bottom left well shows an Arctangle® loading post to deliver uniaxial strain

Figure 39. UniFlex® cell culture plate

Figure 40. UniFlex® culture plate on Arctangle® Loading Stations™

Figure 41. Dimensioned UniFlex® well showing region and orientation of uniaxial strain. Total area = 3.68 cm²

→ Please see page 5 for further information on the Tissue Train® system.
with different Flexlinks. 1 Flexlink can be used for 2 baselines. If running the same program, different programs at the same time only can operate within up to 4 Flexlinks. The Flexcell can be operated with up to 4 Flexlinks. Additional Flexlinks and pumps/producers might be required. The Flexcell can be operated with up to 4 Flexlinks. Additional Flexlinks and pumps/producers might be required.

Please note: Depending on the number of baselines used, additional Flexlinks and pumps/producers might be required.

Compatibility of Flexcell® Tension and Compression Equipment