CLAIMS:

We claim:

1. A method of growing cells in suspension comprising steps of providing a bioreactor with one or more membranes, optionally gas transfer membranes, and moving liquid medium within an extra-capillary space of the bioreactor relative to the membranes.

2. The method of claim 1 wherein the relative movement is provided by movement of the bioreactor.

3. The method of claim 1 or 2 wherein the bioreactor has a longitudinal axis, optionally wherein the bioreactor provides a generally cylindrical plenum for growing cells and the longitudinal axis is a cylindrical axis, and wherein the membranes comprise hollow fiber membranes extending in a plurality of directions perpendicular or oblique to the longitudinal axis.

4. The method of claim 3 wherein the bioreactor is generally cylindrical and the longitudinal axis is a cylindrical axis, or wherein the bioreactor comprises potting heads and wherein the potting heads have interior surfaces forming segments of circles around the longitudinal axis.

5. The method of any of claims 2 to 4 wherein movement of the bioreactor comprises rotating the bioreactor in clockwise and counter-clockwise directions around an axis of rotation passing through the bioreactor.

6. The method of claim 5 wherein the axis of rotation is a longitudinal axis of the bioreactor.

7. The method of claim 5 or 6 wherein the axis of rotation a) is horizontal, b) passes through the center of the bioreactor and/or c) is perpendicular to the membranes.

8. The method of any of claims 1 to 7 wherein the bioreactor is rotated in a pattern including 5 or more reversals of direction and/or decelerations and acceleration (optionally stops and re-starts) in one direction per minute.

9. The method of any of claims 1 to 8 wherein the bioreactor is rotated through less than 360 degrees of rotation in one direction and then through less than 360 degrees in the opposite direction in a repeated pattern.

10. The method of any of claims 1 to 9 wherein the bioreactor is rotated at a speed of rotation in the range of 1 to 25 or 2 to 15 rpm.

11. The method of any of claims 1 to 10 wherein the bioreactor is moved according to any movement described herein, or an analogous movement scaled to a reactor of a different size.

12. The method of any of claims 1 to 11 wherein the bioreactor is inverted and re-inverted.

13. The method of any of claims 1 to 12 wherein the membranes are hollow fiber membranes, the membranes comprise hollow fiber gas transfer membranes, the membranes have an outside diameter of 0.3 mm or more, the membranes are arranged in layers with spaces between adjacent layers, the membranes are spaced apart by at least 0.2 mm in layers, the membrane packing density is 25% or less or 20% or less or 15% or less or in the range of 8-12%, or the volume of an extra-capillary space of the bioreactor is in the range of 1-20, 2-20, or 2-10 mm^3 per mm^2 of surface area of gas transfer membranes.

14. The method of any of claims 1 to 13 wherein the bioreactor operates substantially without a continuous gas phase or headspace, optionally with less than 5% or 4% or 3% or 2% or 1% of the volume of the ECS filled with a continuous gas phase.

15. The method of any of claims 1 to 14 further comprising transferring cells from the bioreactor to a second bioreactor, wherein the second bioreactor is operated according to the method of any of claims 1 to 14.

16. The method of claim 15 wherein the second bioreactor is larger than the bioreactor.

17. The method of claim 16 wherein the bioreactor is rotated at a first speed of rotation and the second bioreactor is rotated at a second speed of rotation, and the second speed of rotation has a lower speed as measured in revolutions per minute than the first speed of rotation.