HSTI_Malaysia

Microgravity Sciences and Space Biology at National Microgravity Laboratory in China

Mian Long

National Microgravity Laboratory and Center for Biomechanics and Bioengineering

Institute of Mechanics, CAS

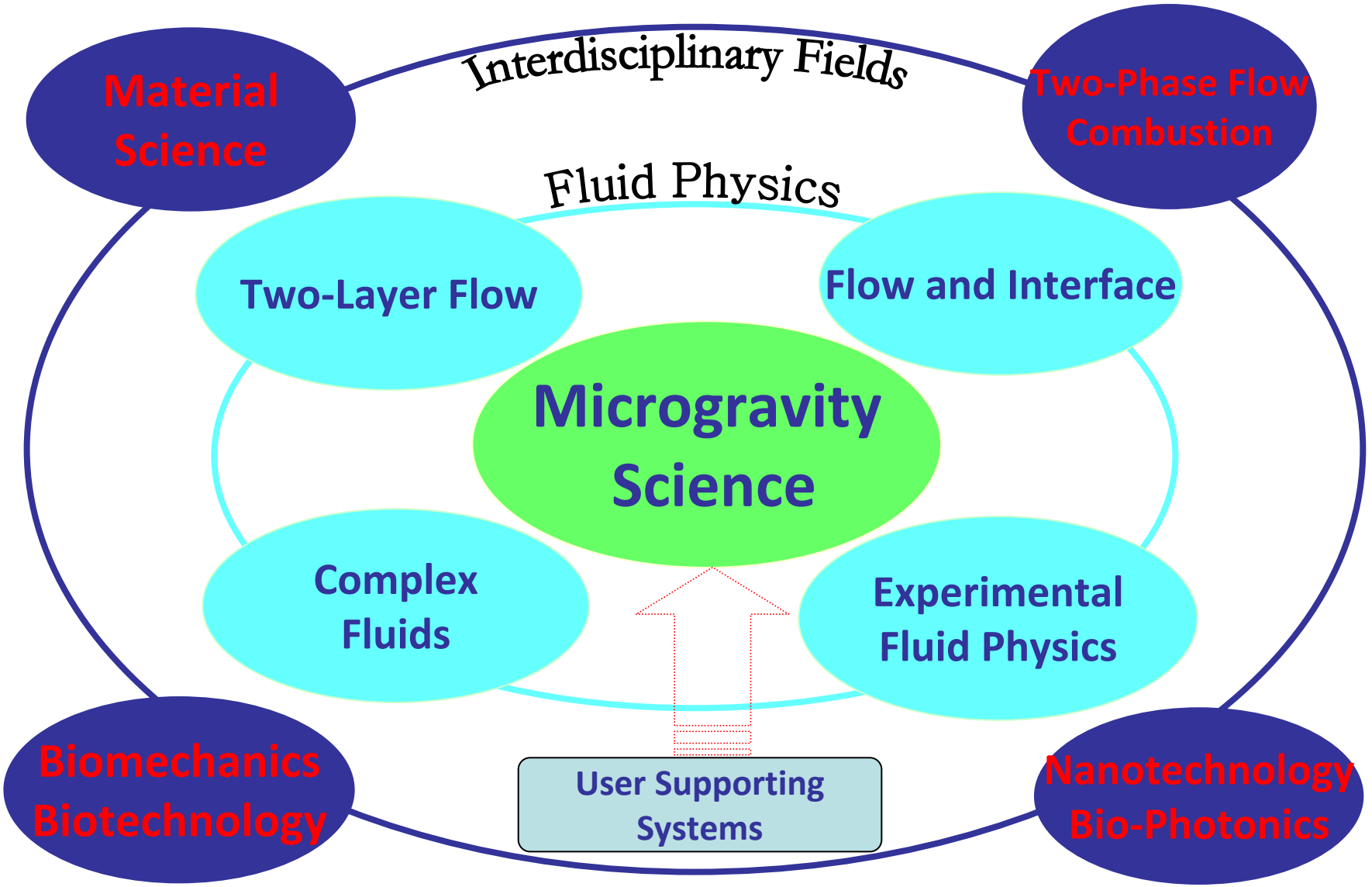
November 14, 2011

Introduction to NML

Historic Events

- 1994：Pre-Approved to found the National Microgravity Laboratory (NML)
- 1995：Approved officially to establish the NML and Prof. Wen-Rui Hu was appointed as the Director of NML
- 1996：Advisory Committee was appointed
- 1998：Main building was completed
- 2003：NML was finally built up
- 2004：Beijing Drop Tower went into action
- 2008：Appointed as the Key Laboratory of Microgravity

Scopes and Aims



Research Team

- Faculties and Staffs： 42
  - Academician： 1
  - Full Professors: 11
  - Associate Professors: 9
  - Assist Professors: 7
  - Engineers and Technicians: 11
  - Others: 3
- Guest Faculties： 12
- Post-Doc and Graduates： 70

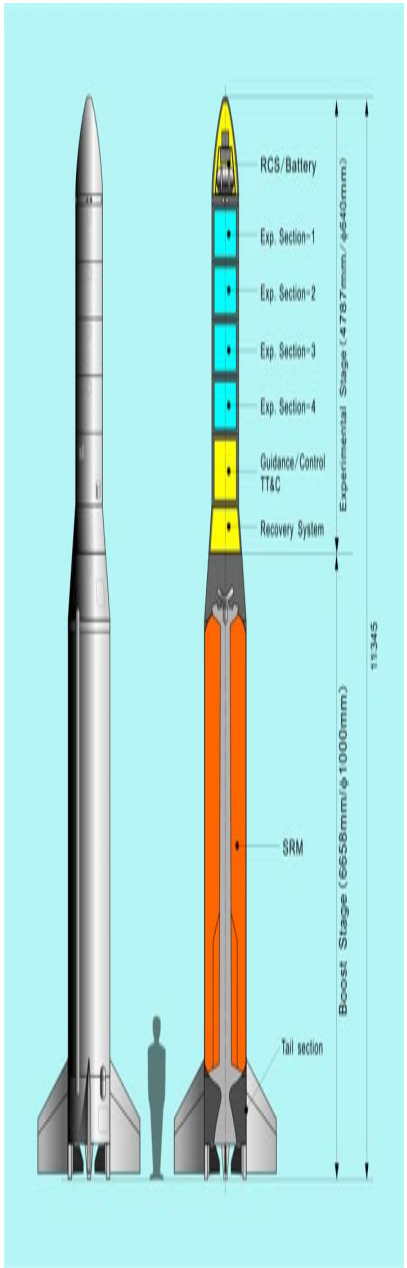
Categories of Research Programs

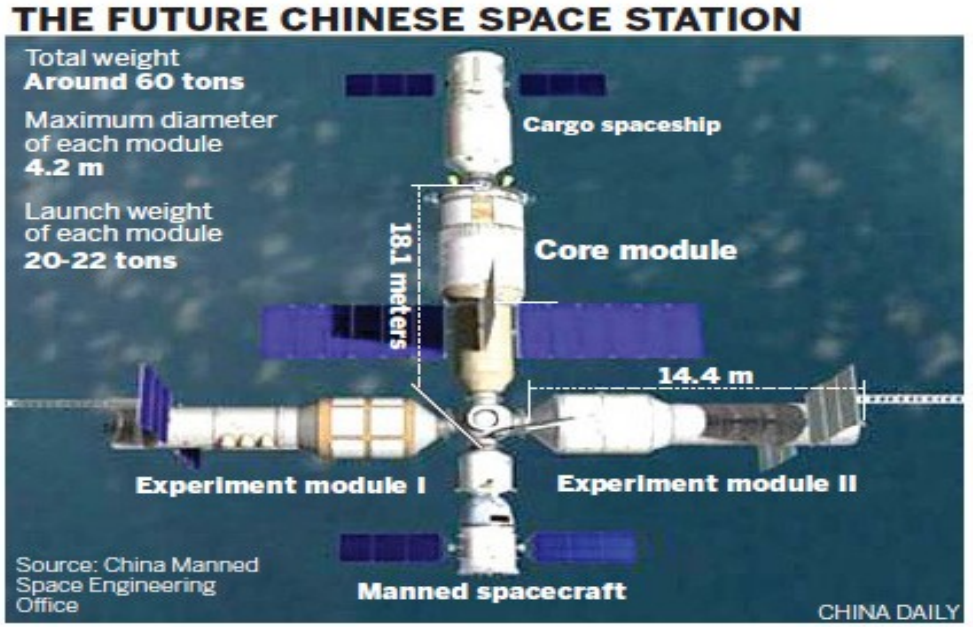
- Ground-Based Studies
  - Projects of basic sciences
- Space Experiments
  - Recoverable Satellites
  - ShenZhou (SZ) Spaceships
  - Sounding Rockets
- Critical Techniques
  - Foundation for further research

Funding Organizations

- China National Space Administration (CNSA)
- China Manned Space Engineering Office (CMSEO)
- Chinese Academy of Sciences (CAS)
- National Nature Science Foundation (NSFC)
- Other Professional Ministries,,,

Microgravity Facility in China





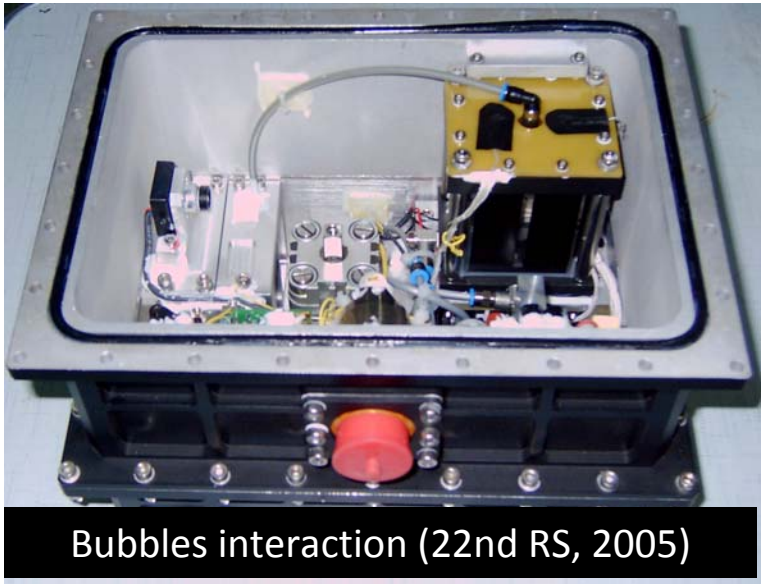
Space Missions at NML (Completed)

- Thermocapillary convection in two-immiscible layer (SJ-5, 1999)
- Gas/liquid two-phase flow pattern (MIR, 1999; collaborated w/KeRC)
- Drop Marangoni migration (SZ-4, 2004)
- Bubbles interaction (22nd RS, 2005)
- Boiling heat transfer (22nd RS, 2005)
- Contact angle measurement (22nd RS, 2005)
- Cell growth and secretion (22nd RS, 2005)
- Pool boiling heat transfer (SJ-8 RS, 2006)
- Mass transfer process (SJ-8 RS, 2006)
- Thermocapillary surface configuration and volume effect (SJ-8 RS, 2006)
- Material stewing combustion (SJ-8 RS, 2006)

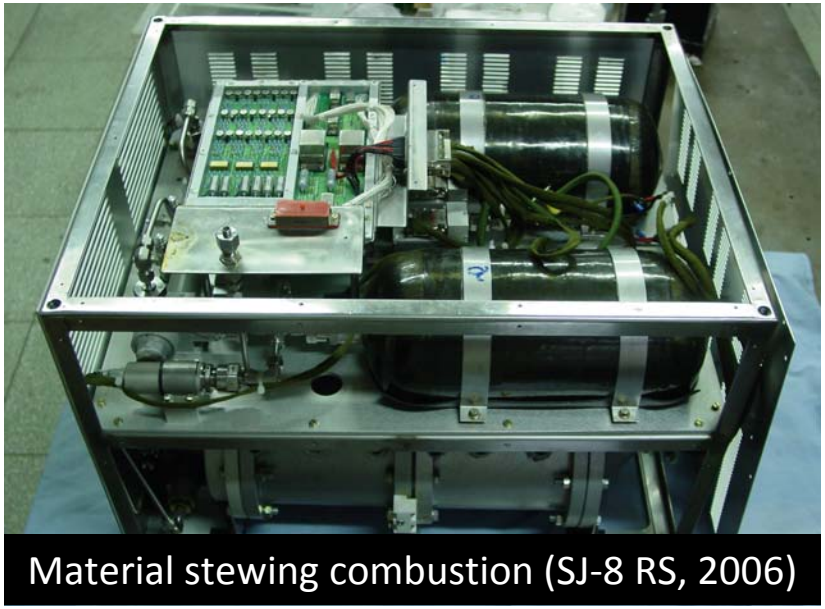
Space Missions (Hardware Facilities)

Thermocapillary convection (SJ-5, 1999)

Drop Marangoni migration (SZ-4, 2004)



Bubbles interaction (22nd RS, 2005)



Material stewing combustion (SJ-8 RS, 2006)

Beijing Drop Tower Facility

- **Top 4th Highest Drop Tower**
  - —Drop Shaft, Lewis Research Center, Cleveland, USA
  - —Drop Shaft, MGLAB, Toki, Japan
  - —Drop Tower, ZARM, Bremen, Germany
  - —Drop Tower, NML, Beijing, China
- **Specified Parameters**

  Drop Tower：3.6 sec， $10^{-5}\times g$，70 kg

  Drop Tube：45 m, ID 200 mm，3.26 sec，$<10^{-6}\times g$
- **Elastic receiver with low impulsion acceleration （<12 g ）**

Research Activities on BJDT Facility

2004-： Test and User Support

2006-： Technical Upgrade (Data acquisition, Control system, Elastic receiver)

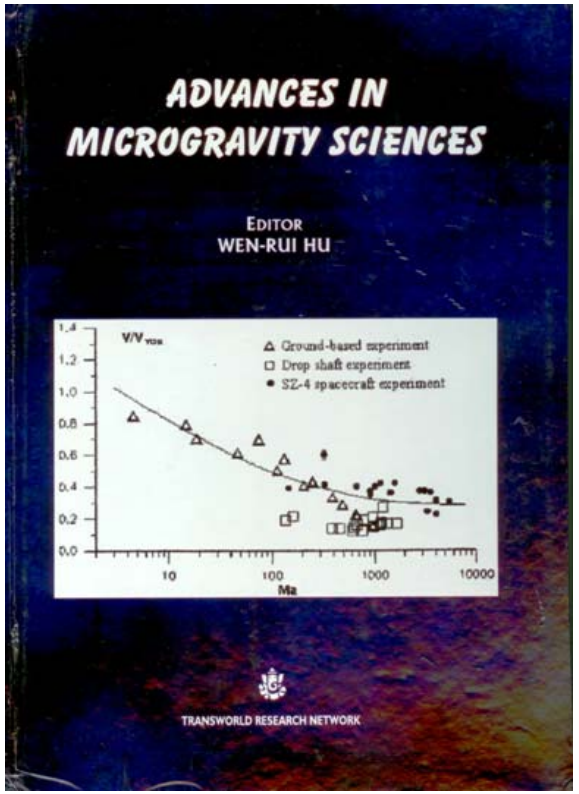
2004-： >10 Institutions/Universities, >400 Experiments for >34 Projects in Fluid Physics, Combustion, and Material Science

Experimental Demo

Migration of Liquid Droplet

Published Book (2009)

Advances in Microgravity Science, WenRui HU, Eds. 2009, Transworld Research Network, India



Chapter 4. Zhao JF. Two-phase gas-liquid flow and pool boiling in microgravity

Chapter 5. Zhang X, Zhang XQ. Candle flames and flame spread over solid materials in microgravity

Chapter 6. Xu SH, Sun ZW. The influence of gravity on the perikinetic coagulation of colloidal suspensions

Chapter 12. Long M, Sun SJ, Huo B, Shu NJ, Tao ZL, Gao YX. Biomechanics on cell responses to microgravity

Special Issue of MST (2008)

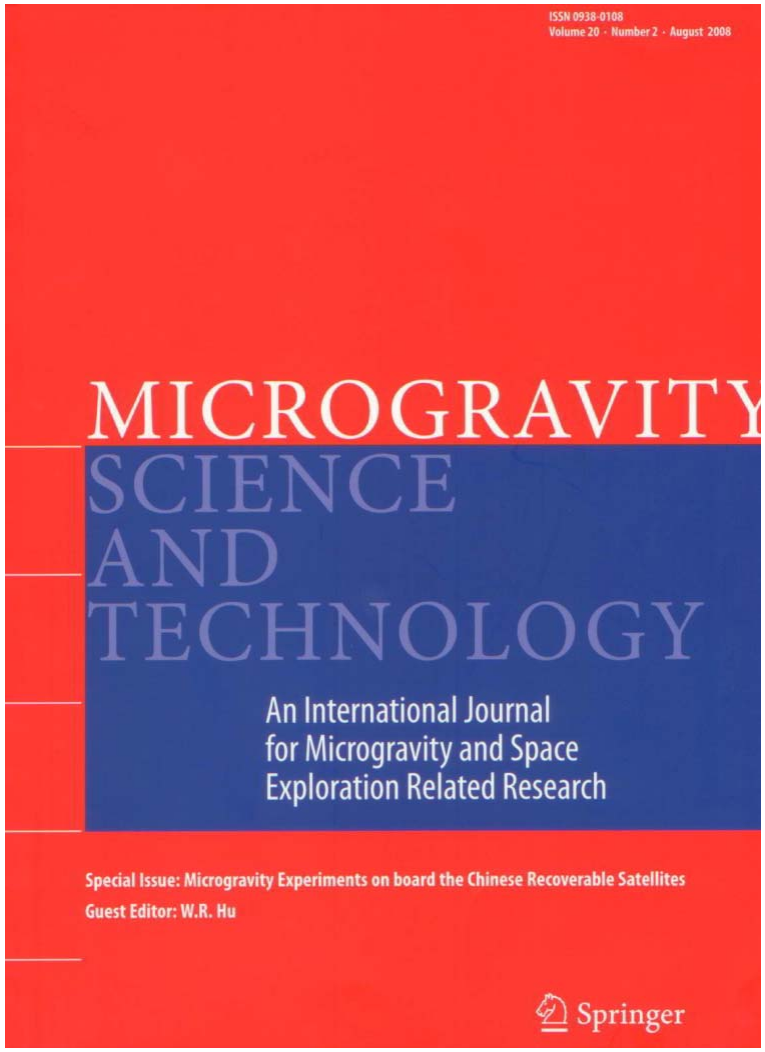
Kang Q, Cui HL, Hu L. and Duan L. On-board Experimental Study of Bubble Thermocapillary Migration in a Recoverable Satellite

Zhao JF, Liu G, Wan SX. Yan N. Bubble Dynamics in Nucleate Pool Boiling on Thin Wires in Microgravity

Duan L, Kang Q, Sun ZW, Hu L, Cui HL, Lin H. Li GP. The Real-Time Mach-Zehnder Interferometer used in Space Experiment

Wang SF. Xia Zhang X. Microgravity Smoldering Combustion of Flexible Polyurethane Foam with Central Ignition

Sun SJ, Gao YX, Shu NJ, Tang ZM, Tao ZL, Long M. A Novel Counter Sheet-flow Sandwich Cell Culture Device for Mammalian Cell Growth in Space



International Collaboration

Germany

- 4 Bilateral Workshops on Microgravity and Space Life Sciences (2000-2009）and 2 International Workshops on Drop Tower (2004-2006)

Russia

- Gas/liquid two-phase flow pattern (MIR, 1999)

Japan

- 7 Bilateral Workshops (1993-2008) and 2 Pacific International Conferences on Microgravity Sciences

France

- 4 Collaborative projects (2006-)

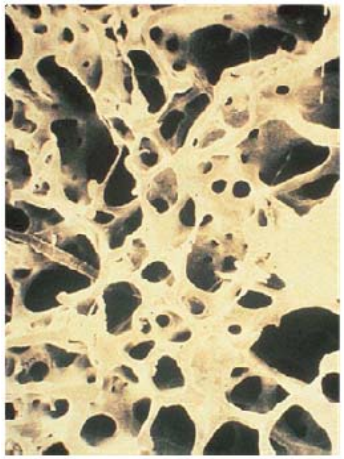
ESA

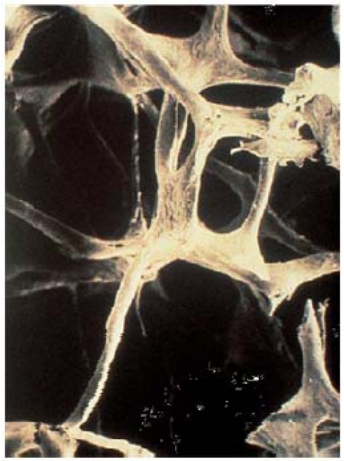
- Diffusion of Oil Components and Measurement of Soret Coefficient (2007-)

Space Life Science at NML

Physiological Issues in Long-Term Flight

Normal bone

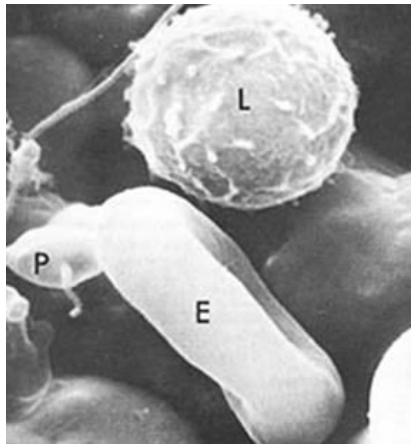


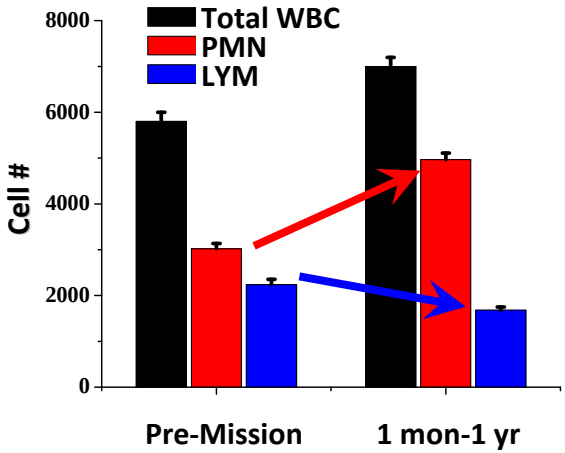


Osteoporosis

Bone loss

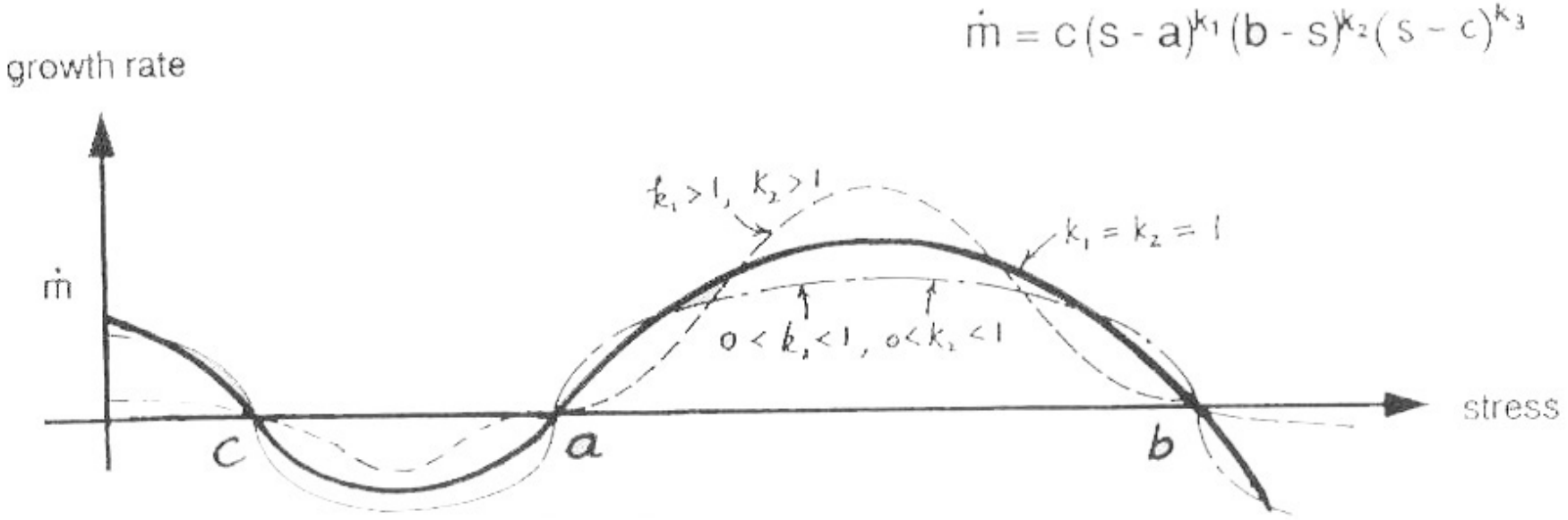
immunosuppression





Call for Biomechanical Rationale

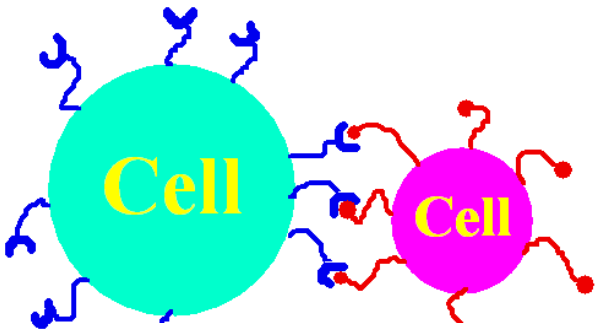
Stress-growth relationship: Biological tissues and organs grow up in a stress field and possess their functions. Under physiological conditions, the stress distributions in tissue and organ comply the need with the function optimization.



Y. C. Fung, 1983

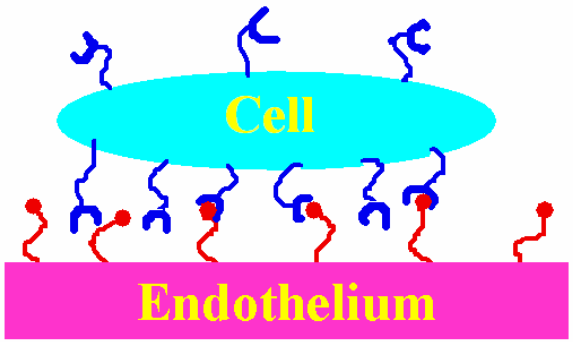
Cell Mechanical-Biological Coupling

- Many mechanically-sensitive proteins (integrin, GPCR,,,)
- Regulation of cell behavirors by mechanical environment
- Trasnduction of mechanical signals into chemical/biological signaling

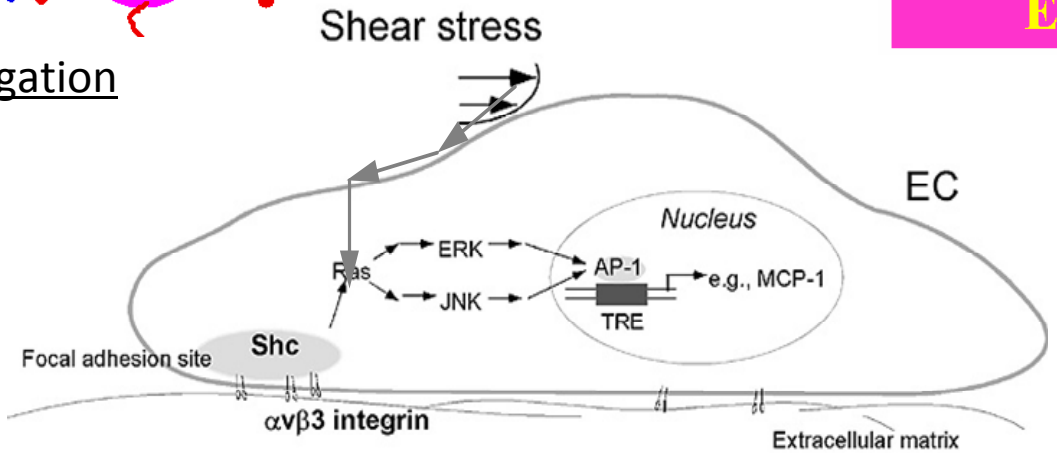


aggregation

Blood flow



adhesion



Transmission and transduction of mechanical signals

Key Scientific Issues

Mechanical-biological coupling mechanism of cellular responses under (micro-)gravity

- How do cells sense gravitational change?
- How do cells adapt gravitational change?
- How do we utilize space microgravity resource?

Combined Effect of Microgravity and Shear

Difficulties for Cell Growth in Space

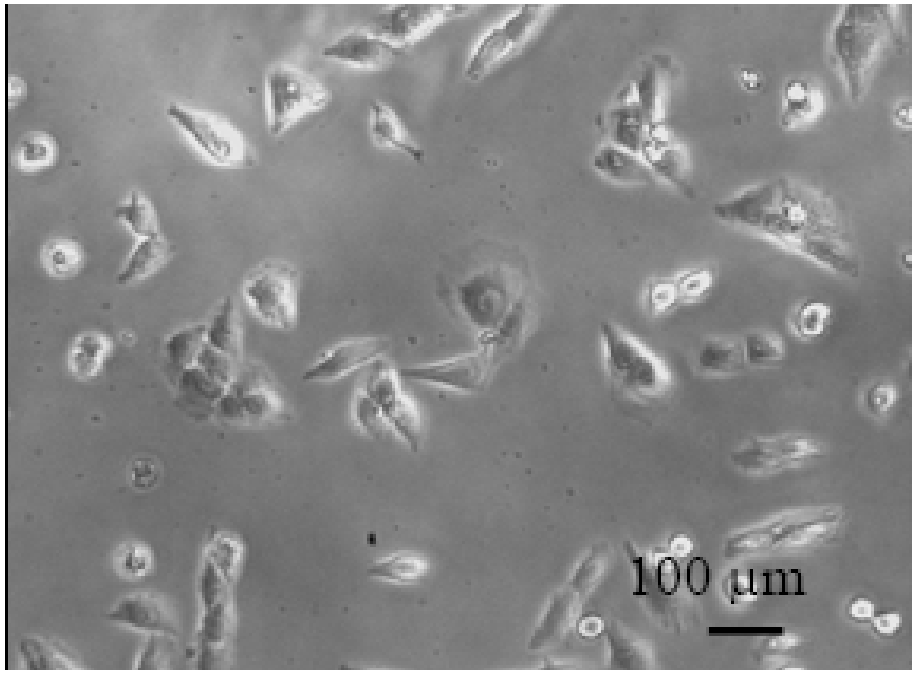
- *No Convection; No Sedimentation*
- *Poor Mass Transport and Nutrient Supply*
- *Hard to Change Culture Medium*

Forced Flow Providing Sufficient Transport

- *Rotary Cell Bioreactor*
- *Counter Sheet-Flow Sandwich Cell Bioreactor*

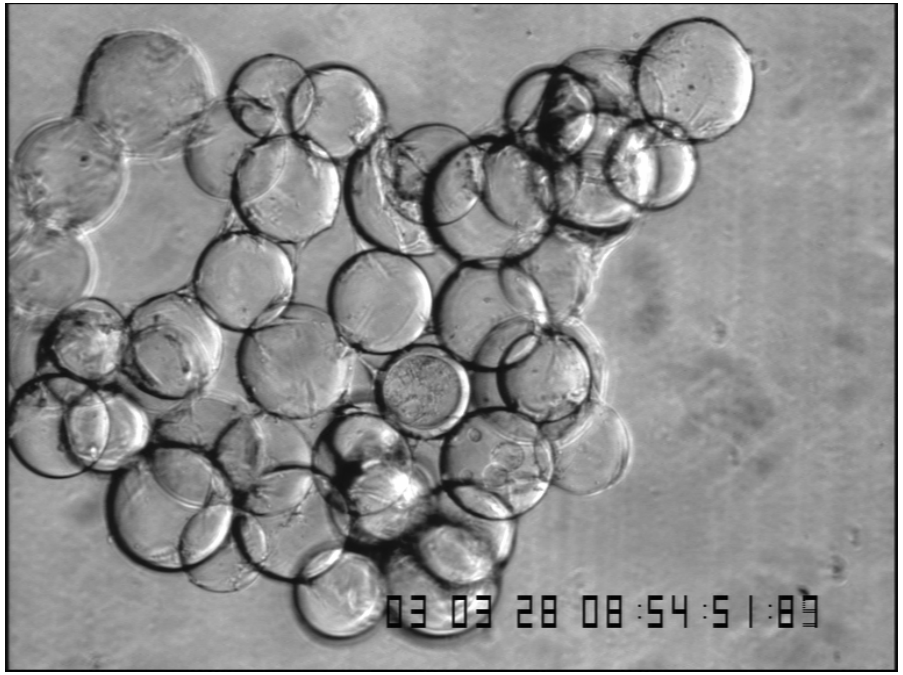
3-D Dynamic Cell Culture Technique (1)

2-D culture → 3-D culture



2-D contact inhibition: limited culture area

Li, Sci. China, 2010

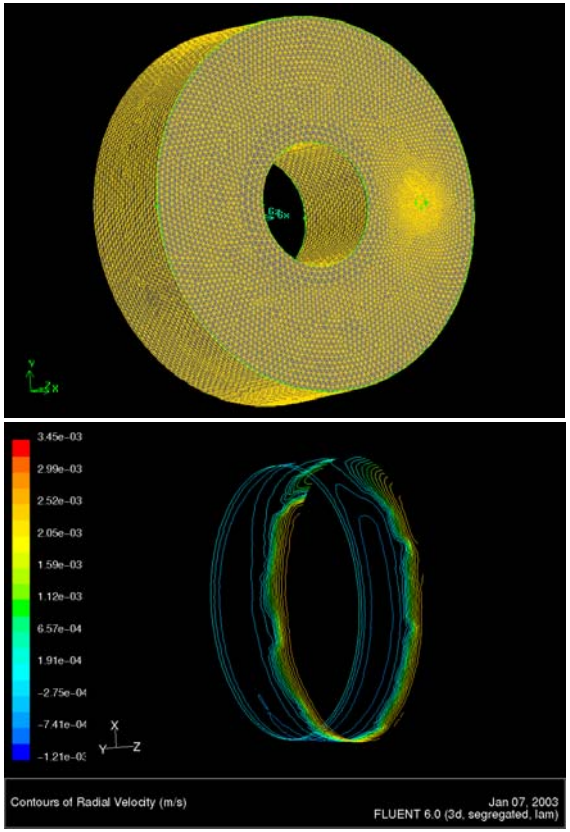


3-D micro-carriers: increased culture area

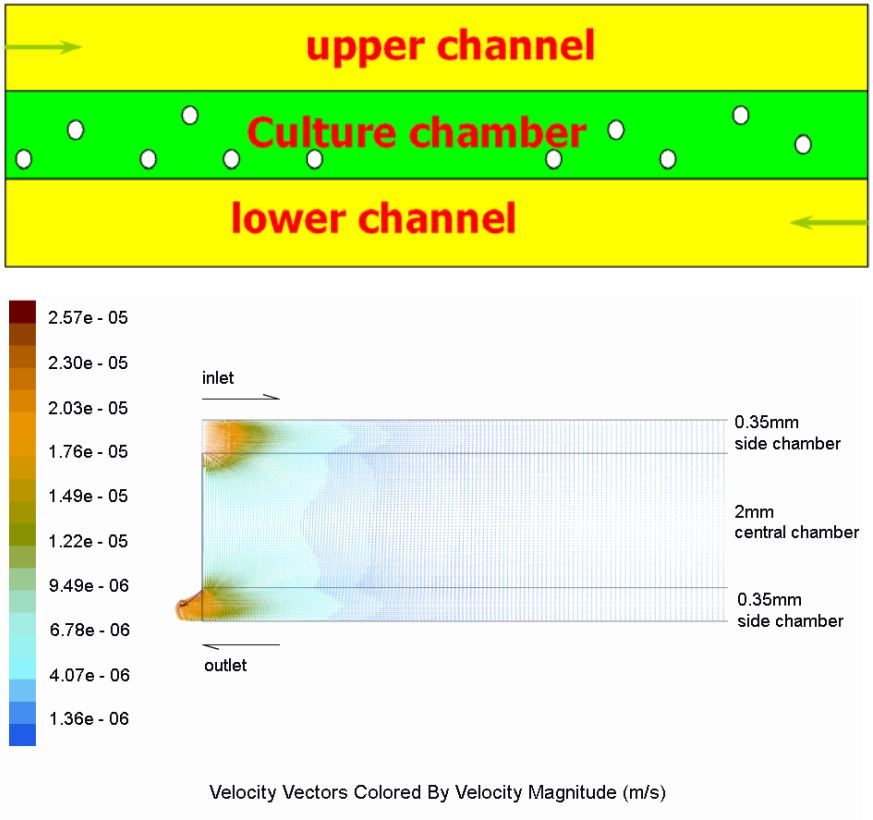
Unpublished Data

3-D Dynamic Cell Culture Technique (2)

Static culture → Dynamic proliferation



Rotating bioreactor

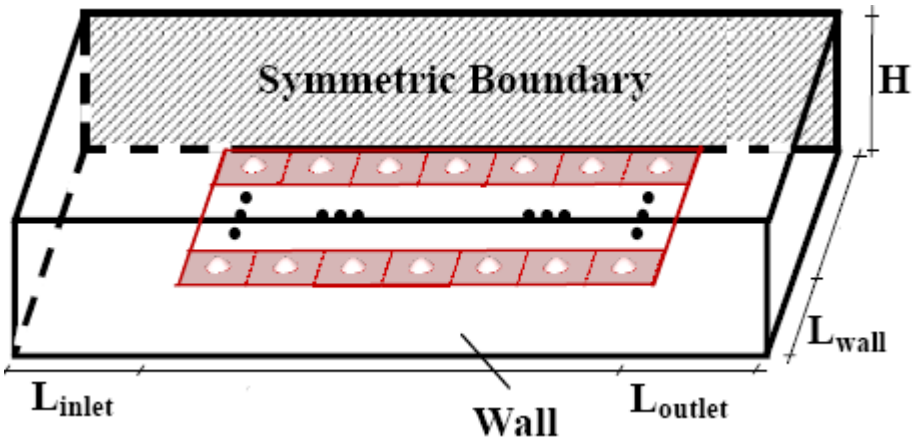


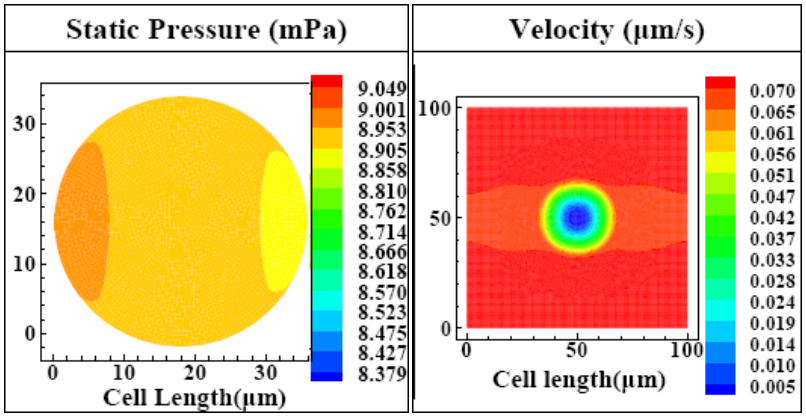
Counter sheet-flow bioreactor

Sun, et al., MST, 2008; Long, et al., In Adv. Microgravity Sci., 2010; Long, et al., In Intro. Microgravity Sci., 2010

3-D Dynamic Cell Culture Technique (3)

Long term culture → Sufficient mass transport



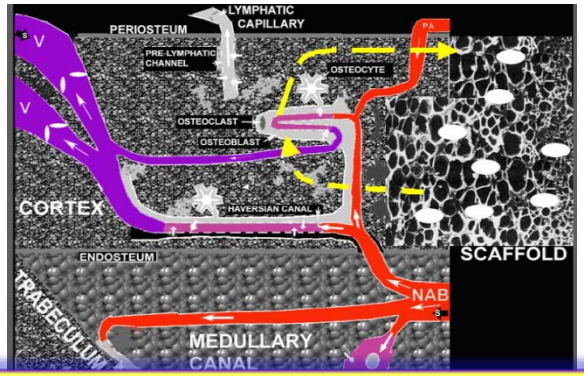


Mass transport around cell

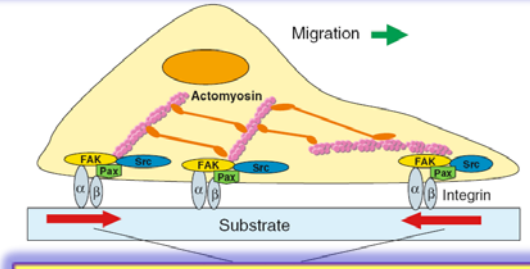
Cui, et al., ABME, 2010

3-D Dynamic Cell Culture Technique (4)

Nutrient supply → Mechanical regulation



Tissue remodeling under mechanical environment

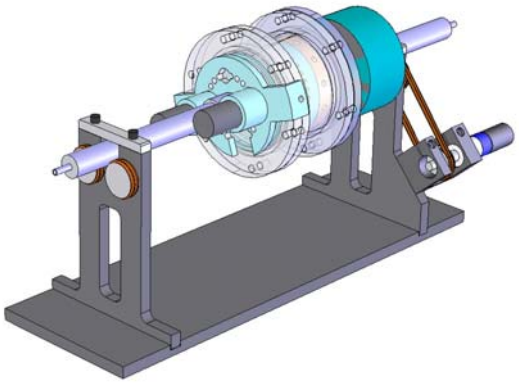


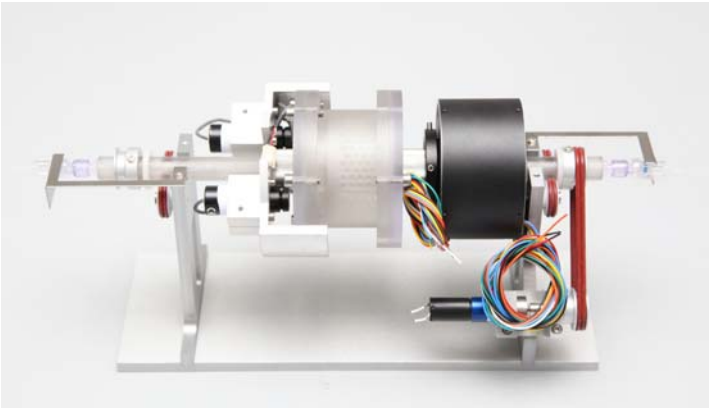
Cell growth mechanical environment

Flow-induced regulation

Cell Culture Bioreactors (1)

Rotary bioreactor



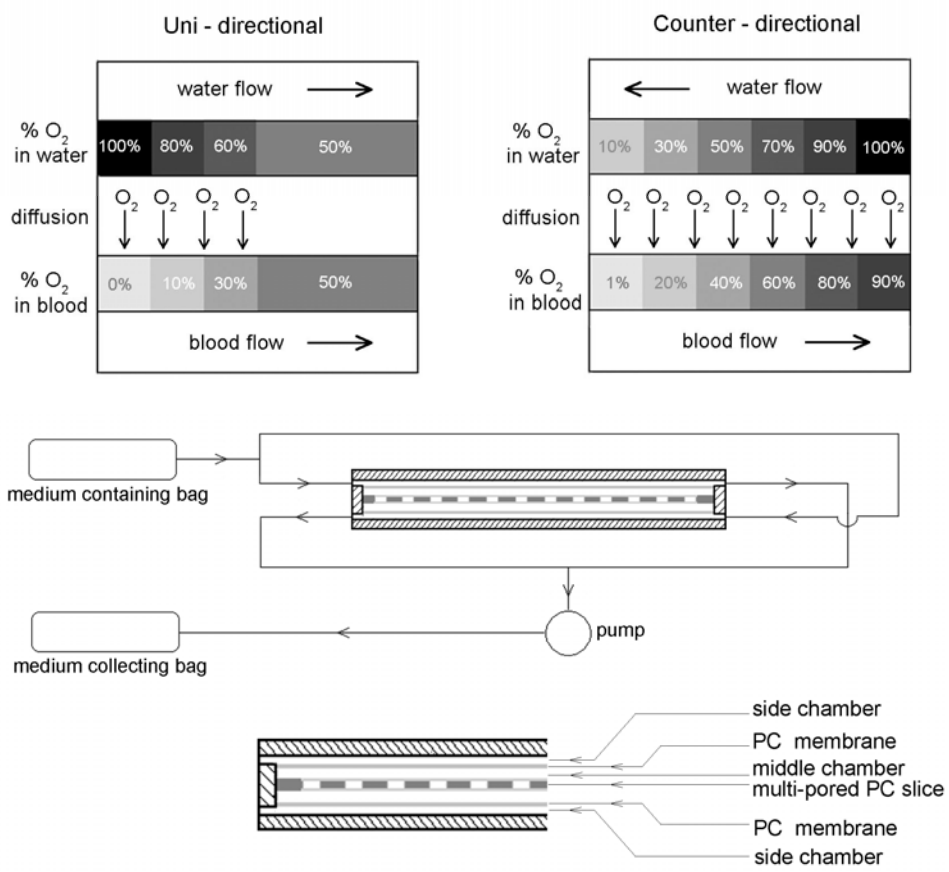


Rotary and perfused bioreactor

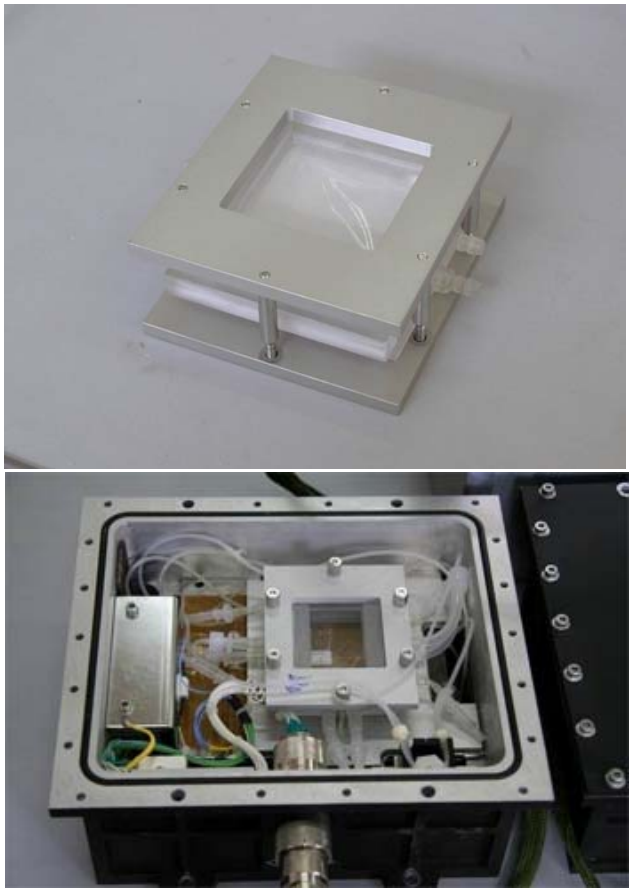
Multi-mode rotary bioreactor

Cell Culture Bioreactors (2)

Counter sheet-flow bioreactor



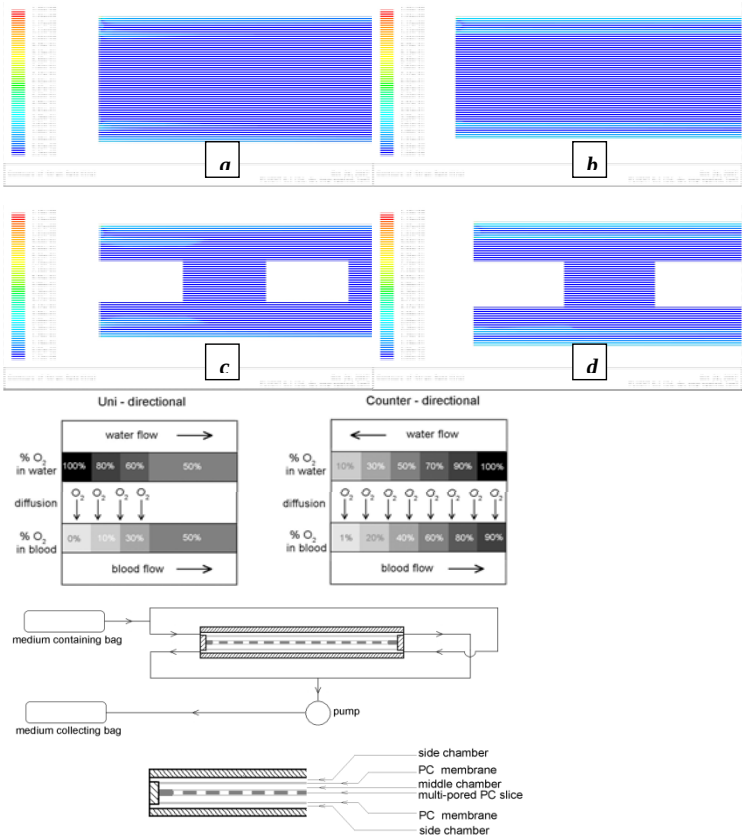
Schematic design based on the principle of biomechanics

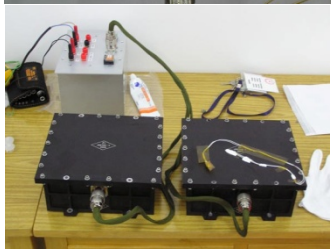


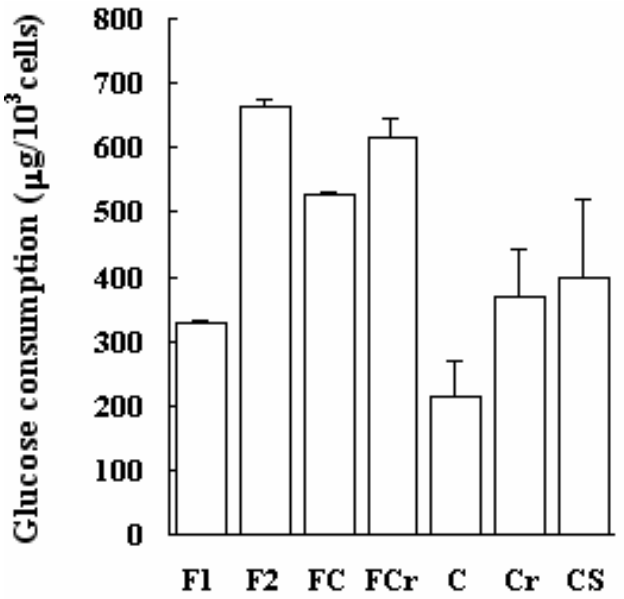
Space payload

Cell Culture Bioreactors (3)

Payload Validation and Secretion Experiment





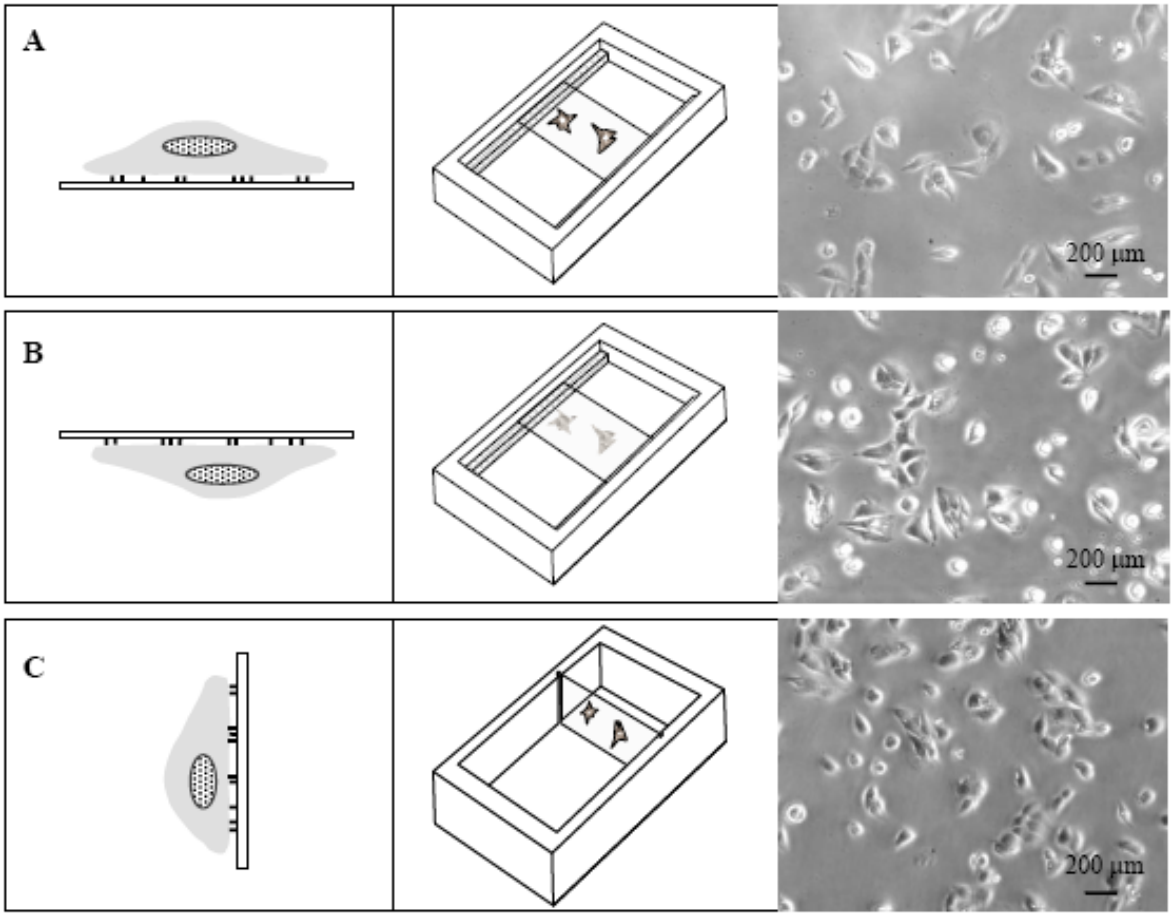


Glucose consumption of trophoblastic tumor cell line (JAR)

(Mission of 22nd Recoverable Satellite, September 2005)

Concept of Gravity-Directed Growth (1)

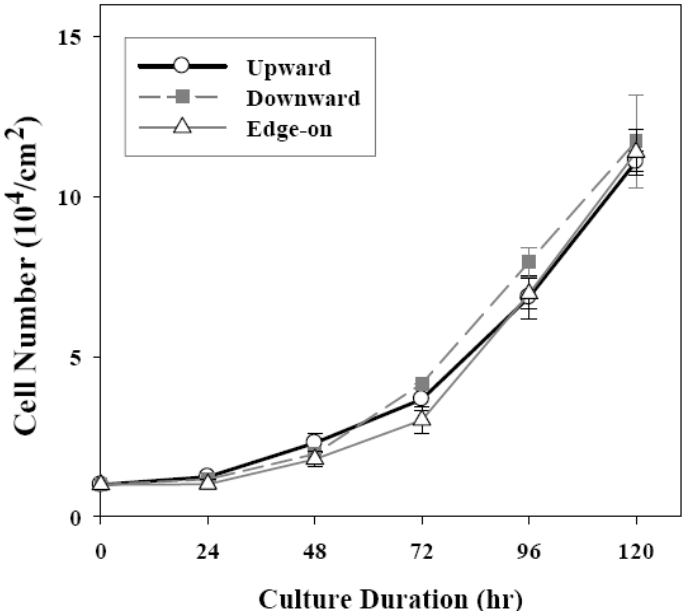
Cell growth on directed gravity

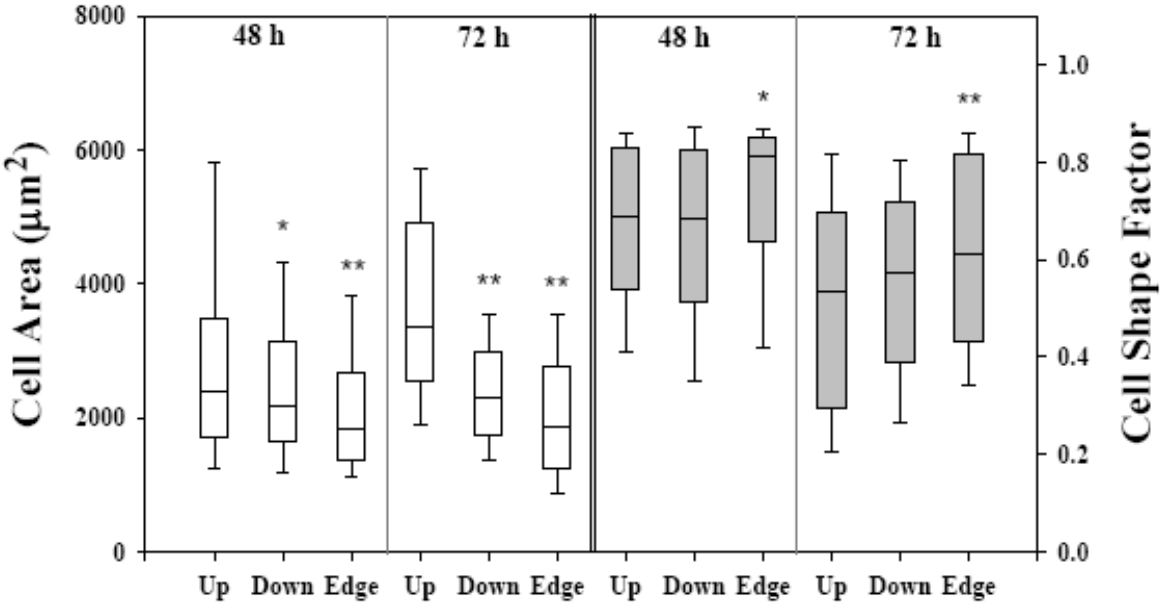


Rat osteosarcoma Ros 17/2.8 cells

Concept of Gravity-Directed Growth (2)

Cell proliferation and morphology

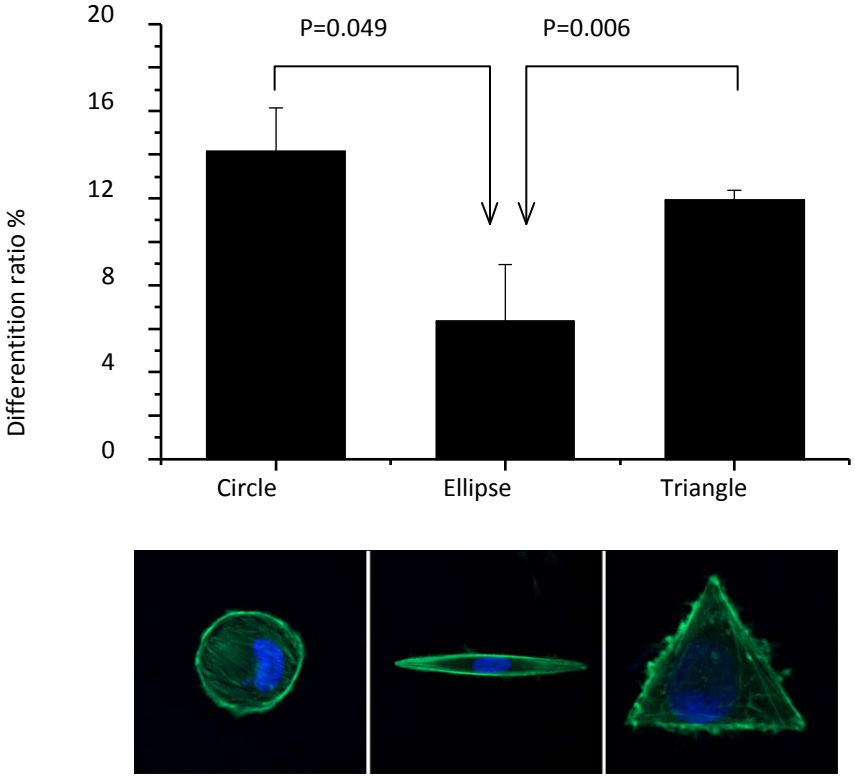




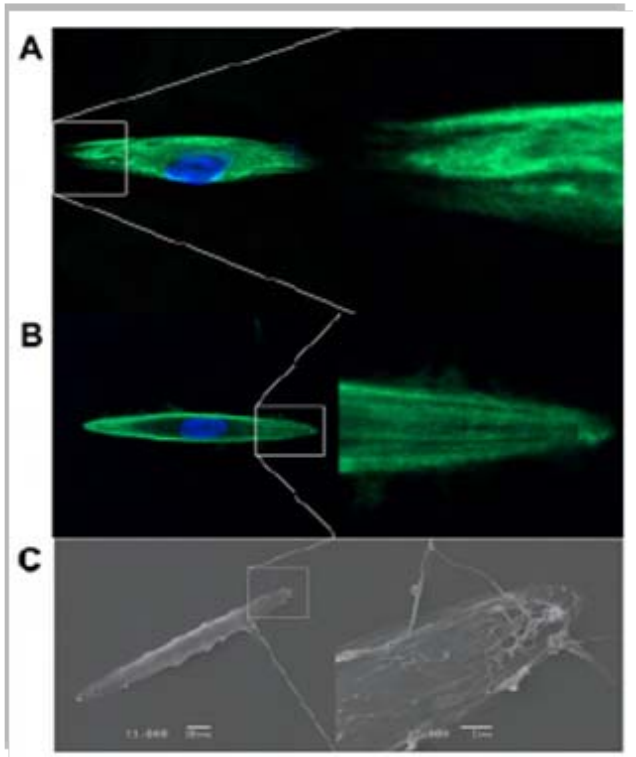
Cell Shape Factor = Perimeter^2/(4 × π × area)

Cellular Mechanical-Biological Coupling (3)

Mesenchymal stem cells



Differentiation of Patterned MSC



Vimentin and F-actin

Li, et al., JMB, 2009

Conclusion Remarks

- Microgravity science and space life science are important fields in CAS.
- Space sciences is one of Strategy Pioneer Programs of CAS.
- Manned space activities is an important activity in China, and CAS responses the utilization system.
- Chinese scientists will contribute more to the international community in science and technology.
- Mechano-biological coupling is an emerging approach for space cell biology.

Thank you for your attentions!!