Life Science with you
I. How tools development push Life Science progress

II. How do fundamental knowledges be applied in biological problem study

III. What's kind of information in Life Science you can use in your field.

IV. Future work in Life Science
How tools development push Life Science Progress

Fundamental knowledge play a key role
Separate organelles of cells by centrifugation.

Drift velocity ~ centrifugal force.
Gel Electrophoresis
Isoelectropoint

Amino acid carry different charge at different pH value
Combine gel electrophoresis and isoelectric focusing (IEF) to form 2D electrophoresis.
Find protein sequence by Chemical degradation and CE

Decide protein sequence
Fluid dynamics help us to design and analyze gathering data.
Solve DNA/Protein structure by X-Ray Crystallography

Diffraction point collection

Fouriers Transform to get structure information
Inspect protein structure by nuclear magnetic resonance (NMR)

Magnetic resonance
Momentum precision

2D Fouriers Transform

Decide molecule structure
(https://tel.life.nthu.edu.tw/)
Medical application
Study molecule dynamic behavior by LASER Trapping/Tweezer

http://www.phys.umu.se/laser/tweezer1.htm
Use Laser trapping to measure kinetics
Use Laser trapping to manipulate cells

Select different cells to contact with each other

Arrange neuron in a special pattern

Axon growth guiding
Explore cell structure by confocal microscope

Green -- F-actin
Red -- mitochondria
3D molecule label

Zebrafish embryo, wholemount, neurons (green), cell adhesion molecule (NCAM, red), (Monika Marks, Martin Bastmeyer, University of Konstanz)

Mouse fibroblasts, cytoskeleton structures (Dr. Iwig, University of Halle)

Rat cerebellum fluorescent staining of astrocyts (green), and Mn superoxide dismutase (red), (Jörg Lindenau, University of Magdeburg)
Understand neuronal connection by confocal microscope
Transmission Electron Microscope

Figure 34-10
Electron micrograph of a T4 phage.
Scanning electron microscope

Photo receptor
Electron diffraction can solve protein structure under 2D crystal

Electron density map

Ion channel model
Use AFM to inspect from um ~ nm scale

Nucleosomal DNA

Actin Filaments
Actin is an important component of contractile myofibrils in skeletal muscle and the cytoskeleton of all animal cells

Living Xenopus Glial Cell

Fr : ww.di.com
Use AFM to analyze antibody/antigen binding

Figure 1: Schematic concept of using AFM to monitor antibody-antigen interaction. (See text for details.)
Use MFM to identify biomagnetics

CLSM image

MFM image

AFM image
wet, glutaraldehyde-fixed chick embryo skin tissue fibroblasts

X-ray optics and microscopy at Stony Brook
When a new tool develops, life science then jump a step. All tool development strongly rely on basic physical / chemical knowledge. You must know how life scientists play their game, their language, then you can perform know their need.
How do fundamental knowledges be applied in biological problem study?

- Mathematics and computer science
- Statistics -- general tools in biology. Since all data need statistical process to make them meaningful.
- Fourier Transform – noise reduction, information extraction.
- Differential equation & difference equation – behavior analysis, kinetic study.
- Model simulation & numerical analysis – experimental data analysis.
- \( \text{etc} \)
Physics

Thermal dynamics – chemical process, transport analysis, cell behavior, tool design

Electronics – experimental design, instrument like biosensor, MEMs

Wave, spectrum, optics & Quantum physics – molecular structure analysis, signal transduction, cell behavior study.

Mechanics – biological mechanics like sport training, supporting analysis.
Chemistry

- Organic - molecule like DNA, protein, drug design, analysis, biosensor design.
- Instrument analysis - chemical process, protein, DNA, RNA, purification, separation.
Mathematics always provide powerful analytical tools. Since the concept of complete set theory, we can reduce inspection noise, filter what we want, or space transform with the assistance of computer or electronic circuit. Remove 60Hz by FT.
From Quantum mechanics, we know that each proton has its resonance frequency since different ambient.

Use Fourier Transform, we can separate the oscillation of each proton.
Biological model can help us to understand or explain your experimental data.

Transport across cell membrane

Passive diffusion

\[ J_x = -D \frac{\partial C}{\partial x} = -D \frac{C_{\text{outside}} - C_{\text{inside}}}{\text{membrane nonpolar thickness}} \]

Facilitated transport (carrier transport)

Enzyme reaction

\[ J_x = \frac{V_{\text{max}}}{1 + \frac{K_m}{C}} \]

Base on model analysis, and experimental data

We can judge if associated protein exist or not
Use thermal dynamics to analyze how membrane potential create...

From thermal dynamics
Diffusion force must balance with electrical field

$$E_{ion} = \frac{RT}{zF} \cdot \ln \frac{[ion]_o}{[ion]_i}.$$  

When multi ions exist, the meta state is membrane potential keep constant but ion still flow with net flow charge flow = 0

$$V_m = \frac{RT}{F} \cdot \ln \frac{(p_K[K^+]_o + p_{Na}[Na^+]_o + p_{Cl}[Cl^-]_o)}{(p_K[K^+]_i + p_{Na}[Na^+]_i + p_{Cl}[Cl^-]_o)}.$$  

(ref. Mathematical Physiology -- James Keener & James Sneyed Springer)

This study let us realize the ion channels composition or properties on membrane
Chemical kinetics help us understand ion channel behavior with experimental data. By model analysis and current experimental data, we can predict how many subunits to form a channel.

Ligand $\rightarrow$ Receptor $\rightarrow$ Ion flow into cell

Outside cell $\rightarrow$ Inside cell

$\sim [\text{Ligand}]^1$

$\sim [\text{Ligand}]^2$

Patch clamp technique
Electrical circuit theory and experimental data help us to realize how action potential create.
Electrical circuit theory and experimental data help us to realize how action propagate.
Base on previous knowledge and model analysis we can explain what we found and guide our next step.

Purkinje cell in cerebellar slice.
Fundamental knowledges can let you enjoy in life science. Some basic knowledge in life science is necessary: biology, biochemistry, molecule biology, cell biology. Keep in mind, don’t forget what you learn when you enter this field. Practice is the real
How knowledge in LS can help you?

Science can let us convenient, keep side effect away. Those fundamental knowledge in life science can help you do some judgement.

Can mobil phone induce any side effect? Cancer, behavior change, headache... or others. Neuroscience & behavior study can help you in your invention. Simulator, game station.

Computer & communication tool
Field of life science can expand your working area

- **Nanostructure** - Enzyme, drug, medical materials like collagen, chitosan...
- **MEMs** - Bio chips, bio-sensor like nose, eye, organs like liver, kidney, lung, micro plant for drug, medical material fabrication, DNA, protein analysis...
- **Mechanics** - Heart, skeleton, robot like hand, legs.
- **Others** - Bio-reactor in pollution removal
- **Complex system for dynamic study** - how thousands of chemical reactions co-work in keeping cells living, body operation.
Life science can provide some models in your area. Energy saving airplane, boat, navigation system. Bioinformation can simplify your system design. Nanostructure – molecule motor, molecule robot, enzyme, drug, material like silk...etc, and electrical generator.
There are many application fields in life science you can enter. Biological systems have already provided very efficient operation processes. They can provide you with good models.
What kind of knowledge do you need to learn?

Keep basic principles of your field in mind.

New learning and working style with current knowledge platforms - networks. Computer language and electrical knowledge - shorten research time and add your capability.

Language in each field. Know how to communicate with different fields.
Knowledge in life science

• Molecule manipulation and metabolism

• The relation of DNA, RNA, and Protein

• Technique of DNA/RNA/Protein engineering – PCR, sequencing, purification, protein synthesis, modification, labeling or marking, protein functions.

• Cell – Cell biology, pharmacology

• What's the money in cell.

• How signal communication inside cell, outside cell, their mechanism, result?

• Knowledge in life science
Development concept? Living?

Behavior – Neuroscience, Ecology

How neuro-circuit programming, learning, and memory.

Sensing, emotion, decision

Communication, competition, adaption, survival
What's kind of treasure you see