

INTERDISCIPLINARY
RESEARCH

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A BRIEF BACKGROUND

- **BSC IN COMPUTER SCIENCE, TECHNION (ISRAEL), 1992-1996**
- **MASTER'S IN COMPUTER SCIENCE, TEXAS A&M UNIVERSITY, 1997-1998 (TESTING OF DIGITAL CIRCUITS)**
- **PHD IN COMPUTER SCIENCE, UT AUSTIN, 1999-2004: FORMAL VERIFICATION (PROF. EMERSON) UNTIL LATE 2000, AND COMPUTATIONAL BIOLOGY (PROF. WARNOW) UNTIL 2004**
- **ASSISTANT PROFESSOR AT RICE UNIVERSITY, 2004 UNTIL NOW**

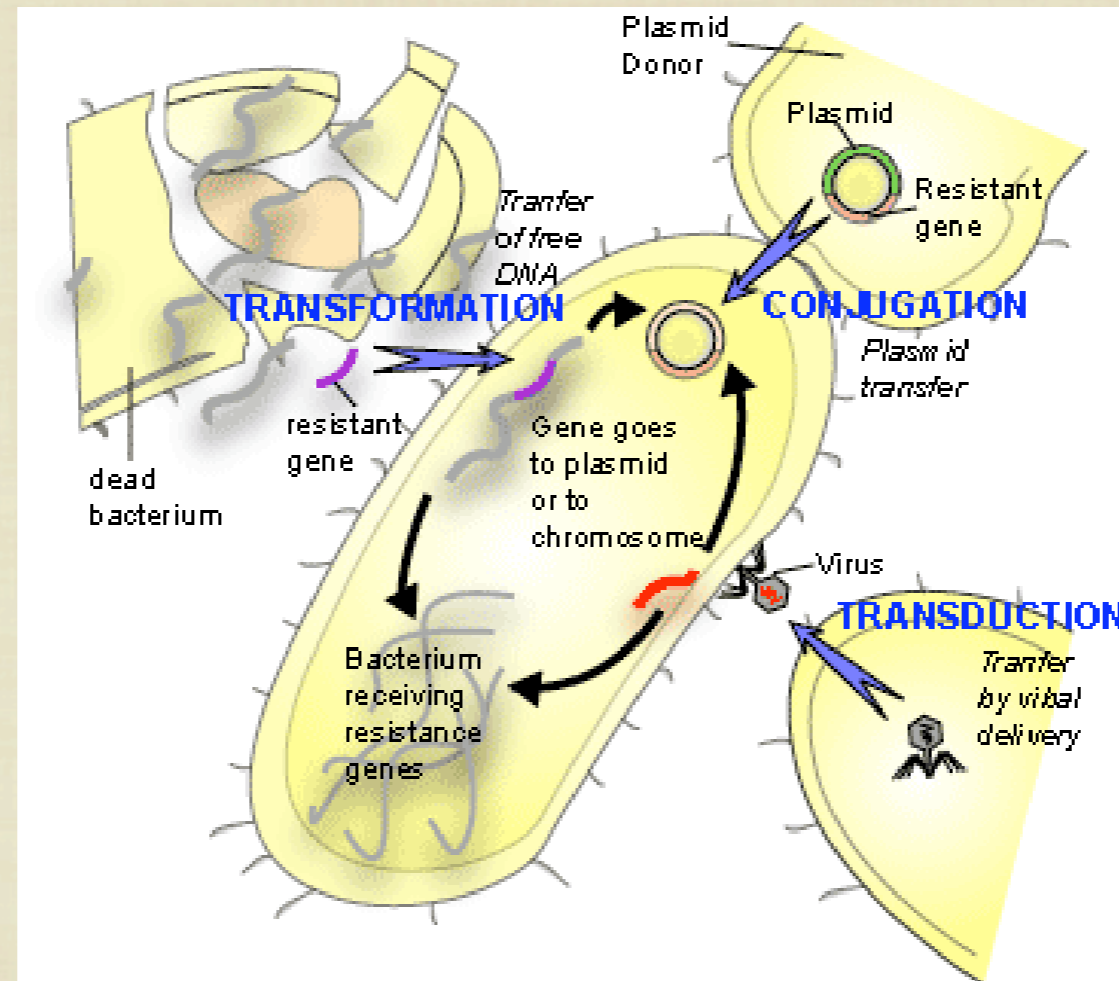
RICE UNIVERSITY AND TMC: INEVITABLE COLLABORATION AND INTERDISCIPLINARITY



HOW IT INFLUENCED MY WORK

- PHD FROM UTCS IN MAY 2004: PHYLOGENETICS
- ASSISTANT PROFESSOR AT RICE U SINCE JULY 2004:
PHYLOGENETICS, SYSTEMS BIOLOGY, GENOTYPE-
PHENOTYPE ASSOCIATIONS, ...

PHYLOGENETICS



SIGNALING IN CANCER

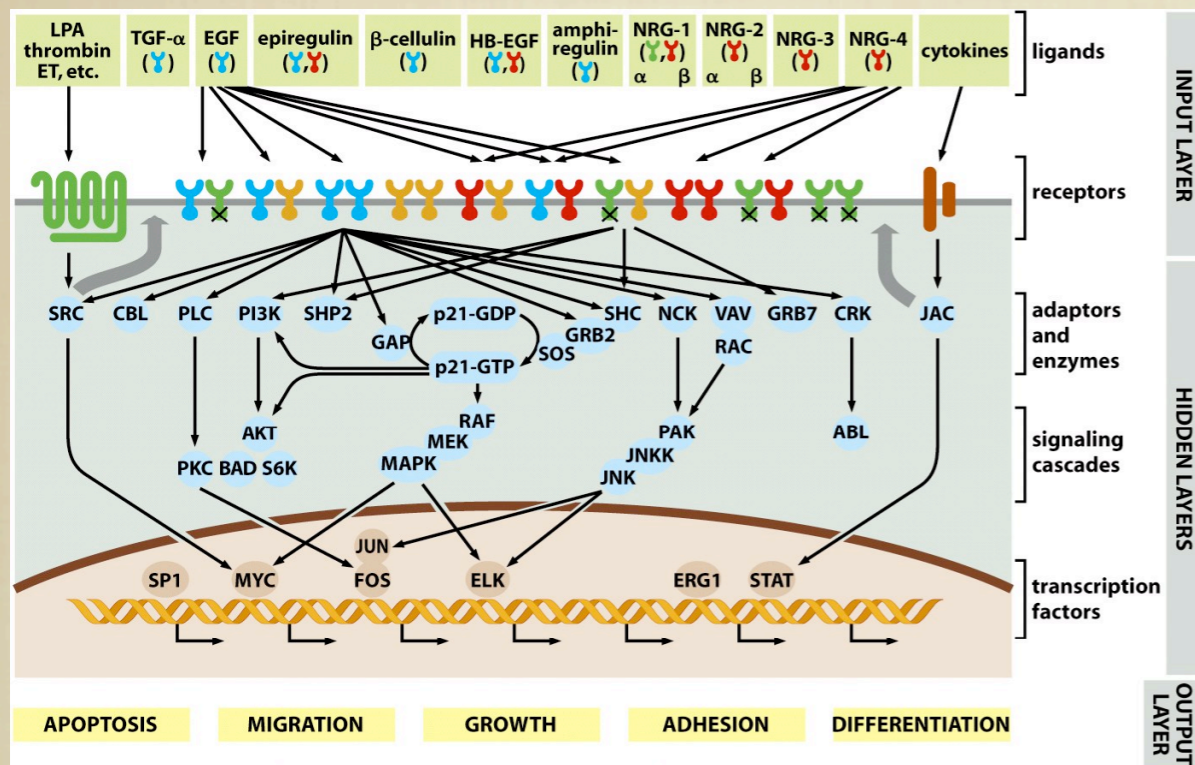


Figure 5-1 The Biology of Cancer (© Garland Science 2007)

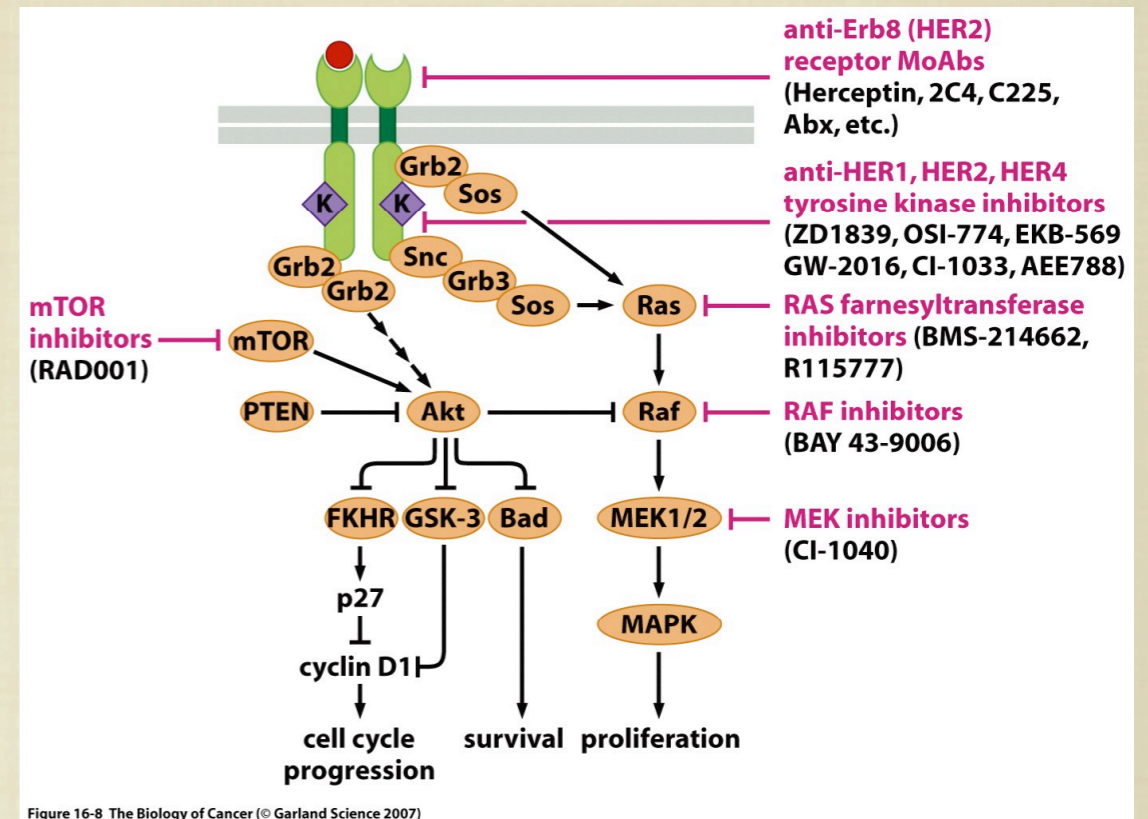
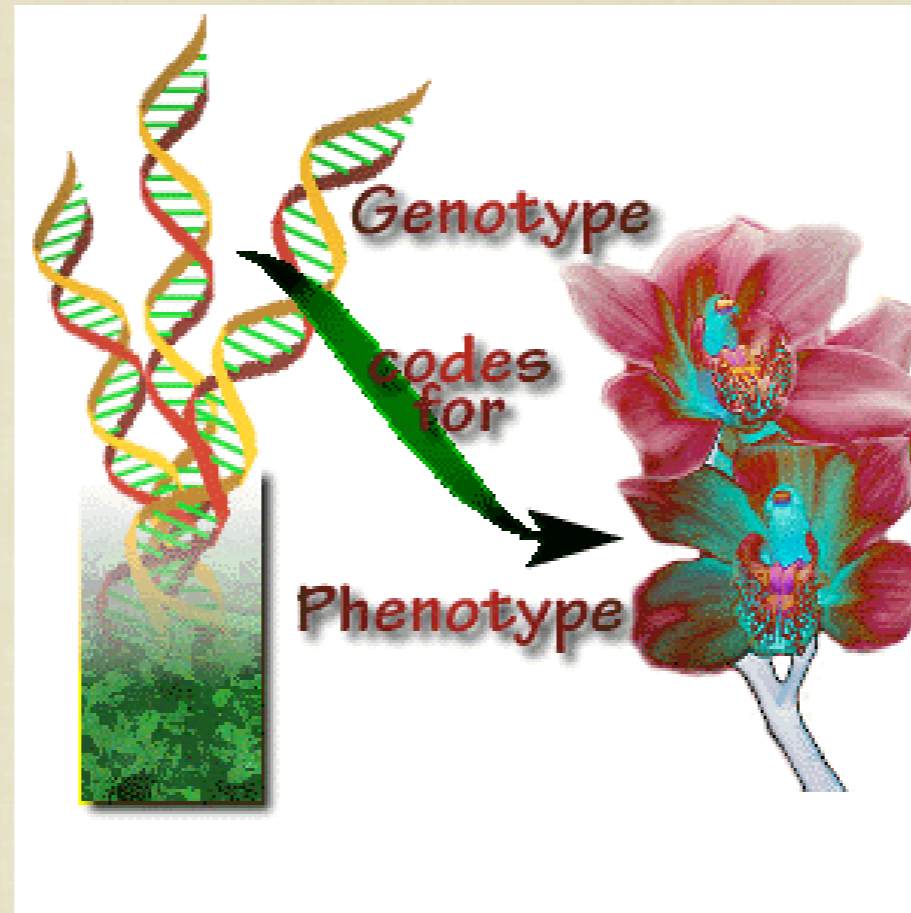


Figure 16-8 The Biology of Cancer (© Garland Science 2007)

GENOTYPE/PHENOTYPE ASSOCIATIONS



HOW IT INFLUENCED MY WORK

- ADVISOR: 7 PHD STUDENTS; COMMITTEE MEMBER: 15 STUDENTS; CO-AUTHORS: 50
- AFFILIATIONS: COMPUTER SCIENCE (RICE), BIOCHEMISTRY AND CELL BIOLOGY (RICE), UT MD ANDERSON CANCER CENTER, BAYLOR COLLEGE OF MEDICINE, AND UT GRADUATE SCHOOL OF BIOMEDICAL SCIENCES
- FUNDING: NIH, NSF, DOE, AND INTERNAL RICE/TMC FUNDS ESTABLISHED SPECIFICALLY FOR COLLABORATIVE/ INTERDISCIPLINARY RESEARCH

INTERDISCIPLINARY RESEARCH



SOURCE: [1]

INTERDISCIPLINARY RESEARCH



SOURCE: [1]

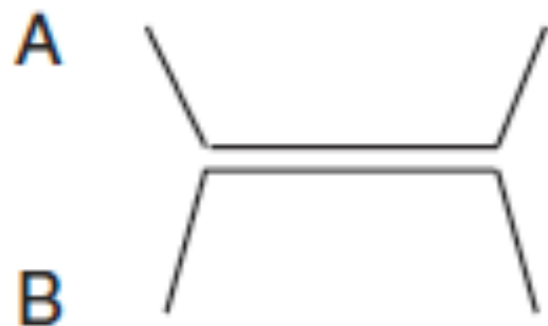
WATSON (A BIOLOGIST) AND CRICK (A PHYSICIST) DISCOVERED THE DOUBLE-HELIX STRUCTURE OF DNA

IDR

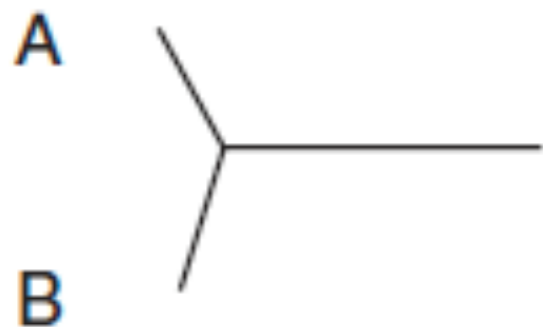
- INTERDISCIPLINARY RESEARCH (IDR) IS A MODE OF RESEARCH BY TEAMS OR INDIVIDUALS THAT **INTEGRATES** INFORMATION, DATA, TECHNIQUES, TOOLS, PERSPECTIVES, CONCEPTS, AND/OR THEORIES **FROM TWO OR MORE DISCIPLINES** OR BODIES OF SPECIALIZED KNOWLEDGE TO ADVANCE FUNDAMENTAL UNDERSTANDING OR TO SOLVE **PROBLEMS WHOSE SOLUTIONS ARE BEYOND THE SCOPE OF A SINGLE DISCIPLINE** OR AREA OF RESEARCH PRACTICE

SOURCE: [1]

MDR vs. IDR



A *Multidisciplinary:*
Join together to
work on common problem,
split apart unchanged
when work is done.



C *Interdisciplinary:*
Join together to
work on common question or problem.
Interaction may forge a new
research field or discipline.

IDR IS A MUST

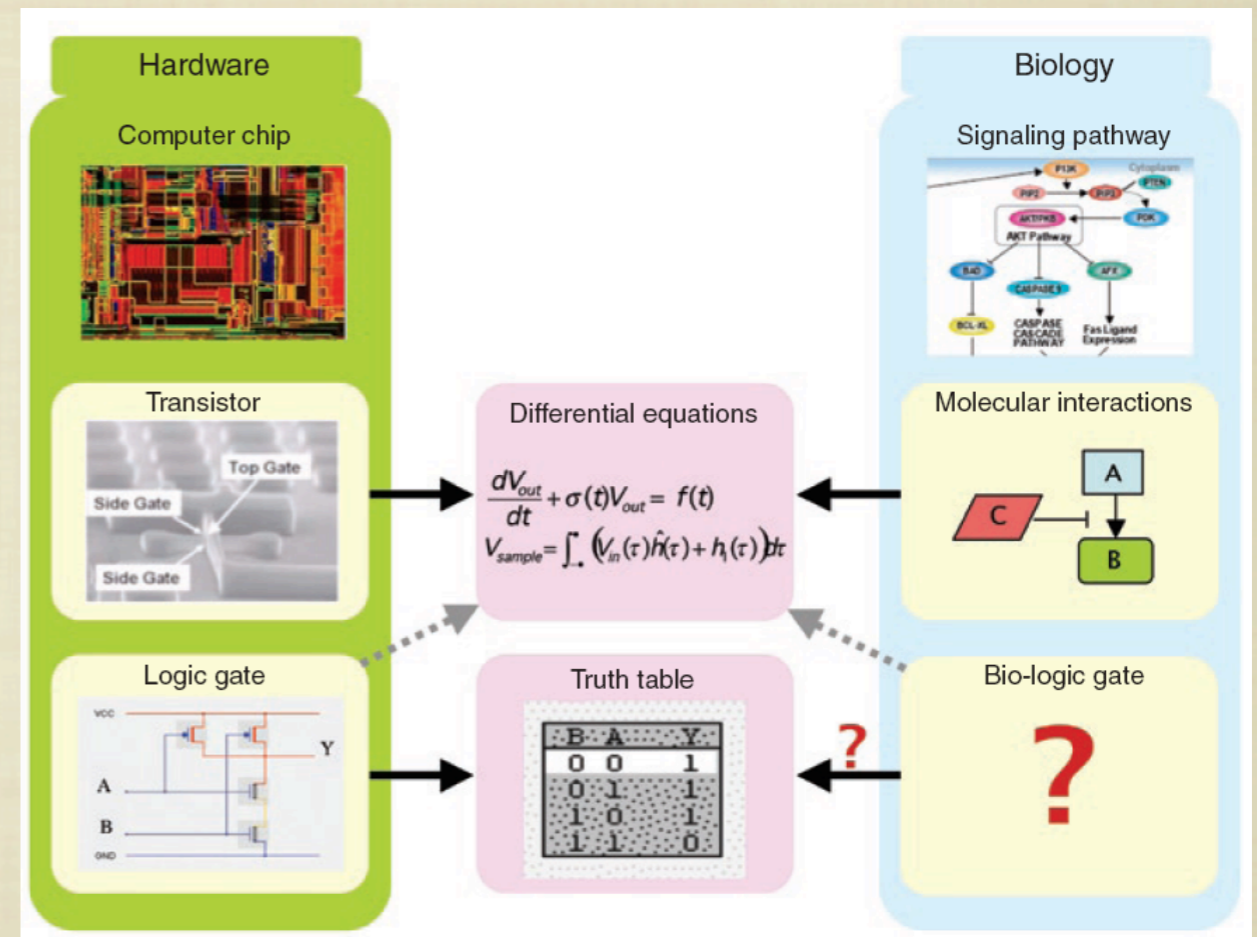
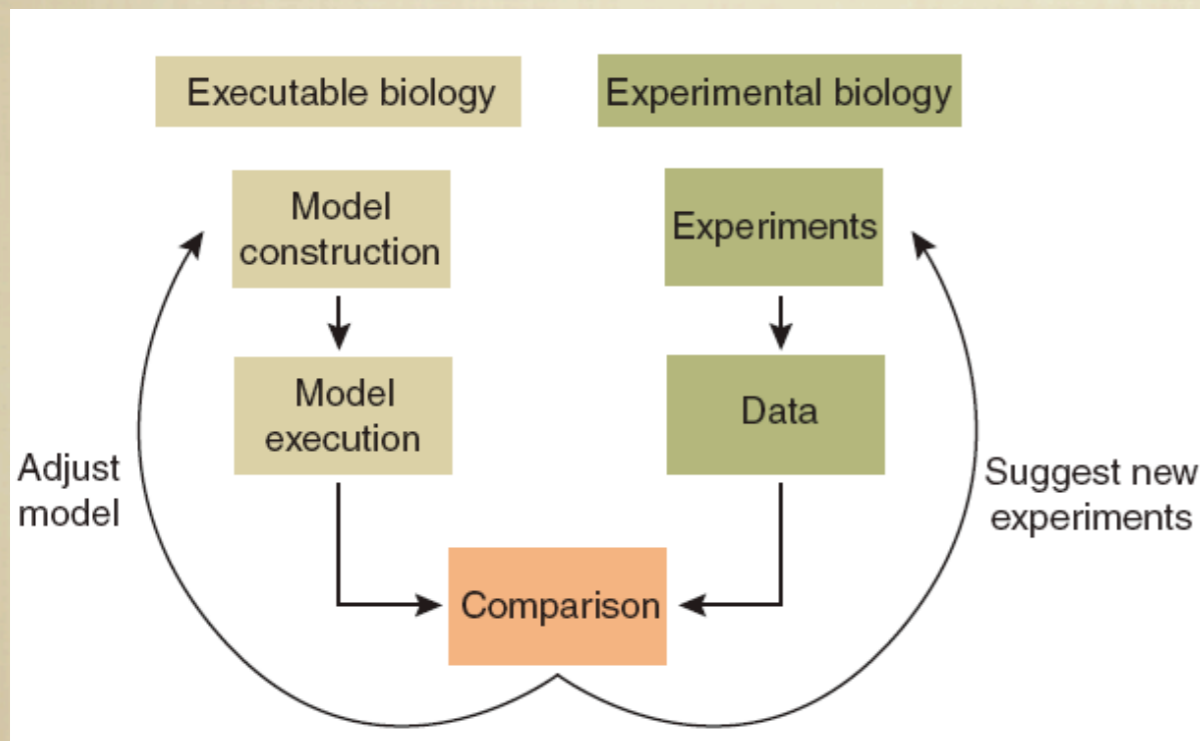
- **“TO CONTINUE TO MAKE PROGRESS ON BASIC SCIENTIFIC QUESTIONS AND ON THE APPLICATION OF NEW KNOWLEDGE TO HUMAN NEEDS, LIFE SCIENTISTS ARE DISCOVERING THAT THEY MUST JOIN IN PARTNERSHIPS WITH PHYSICAL SCIENTISTS AND ENGINEERS. THIS CONVERGENCE OF DISCIPLINES IS THE DEFINING INTELLECTUAL MOVEMENT OF OUR TIME...”**

SOURCE: [2]

EXAMPLE 1: SYNTHETIC BIOLOGY

- A GREAT EXAMPLE OF A TRUE INTERDISCIPLINARY RESEARCH AREA IS SYNTHETIC BIOLOGY, WHICH INTEGRATES BIOLOGY, ENGINEERING, MATHEMATICAL AND COMPUTATIONAL SCIENCES, TO DESIGN AND BUILD NEW BIOLOGICAL SYSTEMS

EXAMPLE 2: EXECUTABLE BIOLOGY



[Figures from: Fisher and Henzinger, Nature Biotechnology, 25(11): 1239-1249, 2007.]

CHALLENGES DRIVING IDR

- SCIENTISTS ARE DRAWN TOWARD “GRAND CHALLENGES” MOST OF WHICH REQUIRE INTERDISCIPLINARY RESEARCH
 1. THE INHERENT COMPLEXITY OF NATURE AND SOCIETY
 2. THE DRIVE TO EXPLORE BASIC RESEARCH PROBLEMS AT THE INTERFACE OF DISCIPLINES
 3. THE NEED TO SOLVE SOCIETAL PROBLEMS
 4. THE STIMULUS OF GENERATIVE TECHNOLOGIES

SOURCE: [1]

KEY CONDITIONS FOR IDR

- **SUSTAINED AND INTENSE COMMUNICATION**
- **TALENTED LEADERSHIP**
- **APPROPRIATE REWARD AND INCENTIVE MECHANISMS**
- **ADEQUATE TIME**
- **SEED FUNDING FOR INITIAL EXPLORATION**
- **WILLINGNESS TO SUPPORT RISKY RESEARCH**

SOURCE: [1]

FACILITATING IDR

THE MOST INTERESTING OBSERVATION IS THAT THE STUDENTS ARE THE INTEGRATING GLUE. GRADUATE STUDENTS, UNDERGRADUATES, AND POSTDOCS ARE THE ONES THAT GO BETWEEN THE LABORATORIES THAT MAKE THINGS HAPPEN.

**HARVEY COHEN, PROFESSOR OF PEDIATRICS
STANFORD SCHOOL OF MEDICINE**

ISSUES FOR IDR FACULTY

- JOINT VS. SINGLE-DEPARTMENT APPOINTMENTS
- JOINT APPOINTMENTS CAN PROMOTE INTERDISCIPLINARY RESEARCH AND EDUCATION
- HOWEVER,
 - DEPARTMENTS HAVE DIFFERENT APPOINTMENT POLICIES; DIFFERENT EXPECTATIONS FOR RESEARCH, TEACHING AND SERVICE; DIFFERENT POLICIES AND PRACTICES ON START-UP FUNDS; DIFFERENT TEACHING LOADS;...
 - TEACHING ASSIGNMENTS ARE MORE COMPLEX
 - AT THE TIME OF TENURE, TWO P&T COMMITTEES MAY HAVE TO BE SATISFIED!

ISSUES FOR IDR FACULTY

- INTERDISCIPLINARY TENURE WITHIN A SINGLE DEPARTMENT
- THE SINGLE GREATEST DIFFICULTY IS THAT FACULTY TEND TO JUDGE OTHER FACULTY ACCORDING TO THE NORMS AND CRITERIA OF THEIR OWN DISCIPLINE
- ANOTHER CHALLENGE IS THE METRICS FOR IMPACT AND SUCCESS (E.G., CONFERENCE PAPERS IN MOST CS AREAS VS. IN OTHER AREAS)
- A THIRD CHALLENGE IS INTERPRETING THE CANDIDATES SUPPORT LETTERS (A LETTER WRITER MAY BE FAMILIAR WITH A PORTION OF THE CANDIDATE'S WORK)

LESSONS FROM MY EXPERIENCE

■ TEACHING:

- STUDENTS IN MY COURSE COME FROM CS, ECE, BIOE, EEB, AND TMC INSTITUTIONS
- STRIKING THE “RIGHT” BALANCE BETWEEN COMPUTATION AND BIOLOGY
- WHAT TYPE OF HOMEWORK AND EXAM QUESTIONS?
- CO-TEACHING
- CROSS-LISTING
- DEPTH, BREADTH, OR NEITHER?

LESSONS FROM MY EXPERIENCE

■ PUBLICATION VENUES:

- MAJOR CONFERENCES ARE MORE “PRESTIGIOUS” YET LESS FOCUSED
- MORE FOCUSED MEETINGS ARE LESS “PRESTIGIOUS”, YET ATTRACT THE LEADING PEOPLE IN YOUR RESEARCH AREA
- FOR BIOLOGISTS, CONFERENCES DO NOT COUNT (YOUR COLLABORATOR(S) MAY NOT WANT TO SUBMIT THERE)
- JOURNALS: A WIDE SPECTRUM OF QUALITY AND BALANCE BETWEEN COMPUTATION/BIOLOGY

LESSONS FROM MY EXPERIENCE

- **SERVICE:**
- **HARDER TO REVIEW PAPERS**
- **SERVING ON COMMITTEES IN OTHER DEPARTMENTS (MAY NOT COUNT IN YOUR DEPARTMENT!)**
- **MORE MEETINGS (I HAVE MET/DINED WITH FACULTY CANDIDATES FROM CS, BCB, EEB, BAYLOR COLLEGE OF MEDICINE, MD ANDERSON CANCER CENTER, UT HEALTH SCIENCE CENTER, AND THE UNIVERSITY OF HOUSTON!)**

LESSONS FROM MY EXPERIENCE

- **MENTORING STUDENTS:**

- **I HAVE 7 PHD STUDENTS WORKING ON PROBLEMS IN BIOLOGY RANGING FROM EVOLUTION OF BACTERIA TO THE ROLE OF SIGNAL TRANSDUCTION IN CANCER. ARE YOU READY TO LEARN ALL THIS BIOLOGY?**
- **ONE OF THE 7 STUDENTS IS A BIOE STUDENT. WHAT BACKGROUND DO YOU REQUIRE?**
- **ARE YOU INTERESTED IN SOMEONE WHO CAN “PROVE THEOREMS” OR SOMEONE WHO CAN DEVELOP CODE, ANALYZE DATA, AND GENERATE HYPOTHESES (THE TWO CATEGORIES ARE NOT NECESSARILY MUTUALLY EXCLUSIVE)**

LESSONS FROM MY EXPERIENCE

- **THE STYLE OF WORK:**
- **COMPUTER SCIENTISTS PREFER “POLYNOMIAL” OVER “EXPONENTIAL”, BUT WHEN N IS THE NUMBER OF NUCLEOTIDES IN A GENOME, AN $O(N^2)$ ALGORITHM IS NOT SUCH A PRACTICAL SOLUTION**
- **IMPLEMENTATION MATTERS!**
- **HEURISTICS WITH GOOD EMPIRICAL PERFORMANCE ARE MORE APPEALING AND USEFUL THAN, SAY, APPROXIMATION ALGORITHMS WITH THEORETICAL BOUNDS**
- **PERFORMANCE (TIME, SPACE, ACCURACY) ANALYSIS IS IMPORTANT**
- **NP-HARDNESS MAY NOT BE AS CRITICAL AS YOU THINK**

LESSONS FROM MY EXPERIENCE

- **THE STYLE OF WORK:**
- **FUNCTIONALITIES AND USER INTERFACE (MOST COMMONLY-USED TOOLS IN PHYLOGENETICS ARE WRITTEN BY BIOLOGISTS, NOT COMPUTATIONAL SCIENTISTS!)**
- **DATA ANALYSIS IS CRUCIAL IF YOU WANT TO ACHIEVE HIGH IMPACT (PARTICULARLY IF YOU'RE INTERESTED IN A SCIENCE/NATURE PAPER)**
- **LEARN ABOUT THE OTHER DISCIPLINE(S) AS MUCH AS POSSIBLE (NOT JUST THE LANGUAGE)**
- **THINK OF INTERESTING BIOLOGICAL QUESTIONS; DON'T THINK OF YOURSELF AS JUST A PROBLEM SOLVER; FORMULATING AN IMPORTANT BIOLOGICAL QUESTION IS AS IMPORTANT AS (OR, EVEN MORE) SOLVING IT**

LESSONS FROM MY EXPERIENCE

- **THE STYLE OF WORK:**
- **COMPUTATIONS ARE FAST, CHEAP, AND AUTOMATED; EXPERIMENTS (THE REAL ONES) ARE SLOW, EXPENSIVE, AND REQUIRE MANUAL INTERVENTIONS**
- **BE PATIENT**
- **BE PREPARED FOR SPENDING A YEAR OR TWO TO GET ONE PUBLICATION (DO YOU PREFER TO SPEND 2 YEARS TO GET A NATURE ARTICLE OR TO PUBLISH 3 WORKSHOP ARTICLES A YEAR?)**
- **AUTHORSHIP SYSTEM IS DIFFERENT (VERY DIFFERENT)**

LESSONS FROM MY EXPERIENCE

- **THE STYLE OF WORK:**
- **YOUR BIO COLLABORATOR WANTS “BIOINFORMATICS”; DOES HE/SHE MEAN RESEARCH OR SYSTEM ADMINISTRATION / DATABASE SUPPORT?**
- **BIOLOGY IS VERY EXCITING AND MANY PROJECTS MAY INTEREST YOU; MAKE SURE YOU DEVOTE AT LEAST 75% OF YOUR TIME AND EFFORTS AT THE BEGINNING TO YOUR OWN PROJECT, WHILE SPENDING THE OTHER 25% LEARNING AND GETTING INVOLVED IN NEW ONES**

BEFORE YOU GRADUATE

- TAKE AS MANY COURSES IN AS MANY AREAS AS POSSIBLE
- RESPECT THE “OTHER” DISCIPLINE: “BIOLOGY IS EASY AND CS IS HARD” IS A MYTH; LEARN THE BIOLOGY AND YOU’LL SEE UNPRECEDENTED COMPLEXITY
- INTEGRATE WORKS FROM MULTIPLE DISCIPLINES
- YOU MAY WANT TO CONSIDER A POST-DOC POSITION AS YOUR PRIMARY GOAL (NOT AS A BACKUP OPTION)
- AGAIN, DO NOT ACT AS A “PROBLEM SOLVER”; FORMULATE PROBLEMS AS WELL, PARTICULARLY BIOLOGICALLY-RELEVANT ONES

CONCLUSIONS

- **IDR IS A MUST IN MANY AREAS, AND HAS ALREADY LED TO BREAKTHROUGHS**
- **IDR DOES NOT COME WITHOUT CHALLENGES; IN FACT, IT COMES WITH MANY CHALLENGES AT ALL LEVELS**
- **FOR THOSE ASPIRING TO BECOME FACULTY MEMBERS, REMEMBER: TENURE IS ONE GOAL; IT SHOULD NOT BE THE ONLY GOAL; IF THE PLACE IS NOT SUPPORTIVE OF IDR, YOU MAY WANT TO CONSIDER OTHER PLACES**

FURTHER READING

- [1] “FACILITATING INTERDISCIPLINARY RESEARCH”, A REPORT BY THE NATIONAL ACADEMY OF SCIENCES, NATIONAL ACADEMY OF ENGINEERING, AND INSTITUTE OF MEDICINE (AVAILABLE FROM [HTTP://WWW.NAP.EDU/CATALOG/11153.HTML](http://www.nap.edu/catalog/11153.html))
- [2] “THE ROLE OF LIFE SCIENCES IN TRANSFORMING AMERICA’S FUTURE: SUMMARY OF A WORKSHOP”, A REPORT BY THE COMMITTEE ON A NEW BIOLOGY FOR THE 21ST CENTURY. (AVAILABLE FROM [HTTP://WWW.NAP.EDU/CATALOG/12592.HTML](http://www.nap.edu/catalog/12592.html))
- [3] “BEST PRACTICES MEMO: PROMOTION AND TENURE OF INTERDISCIPLINARY FACULTY”, A REPORT BY THE COMPUTING RESEARCH ASSOCIATION (AVAILABLE FROM [HTTP://WWW.CRA.ORG/REPORTS/PROMOTION_TENURE.HTML](http://www.cra.org/reports/promotion_tenure.html))

THANK YOU

[HTTP://WWW.CS.RICE.EDU/~NAKHLEH](http://www.cs.rice.edu/~NAKHLEH)

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