

Ph.D. Training in Cancer Biology

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Introduction

Cancer is one of the major afflictions of mankind. In recent years, knowledge about the origins, growth, tissue interactions, and spread of cancer has burgeoned. Descriptive knowledge has been replaced by mechanistic understanding of cancer behavior at the molecular, cellular, and organismal levels. Concomitant with the development of this extensive body of knowledge has been the development of scientists devoted to the elucidation and solutions of problems of cancer biology.

Cancer biology is a unique, interdisciplinary biomedical science that encompasses experimental approaches and didactic knowledge from biochemistry, cell biology, epidemiology, genetics, immunology, microbiology, pharmacology, molecular biology, pathology, and physiology. Cancer biology also is closely allied to the clinical oncologic sciences that are involved in human cancer prevention, detection, diagnosis, and treatment.

The cancer biology training consortium involves leaders of predoctoral and postdoctoral research and educational training at institutions in the United States. Recognizing that cancer biology is a distinct but highly interdisciplinary scientific discipline, our goal is to define a curriculum that will train new investigators intensively in fundamental and translational approaches to cancer biology and to provide lifelong skills that will enable students to contribute to extinction of cancer as a major problem of human health.

To this end, a major goal of the consortium is to establish guidelines for trainees in cancer biology including:

- education in the experimental science of cancer biology that encompasses both didactic and nondidactic learning
- research training in the experimental science of cancer biology, and
- career development as independent cancer biologists

These aims are closely allied to those of the National Cancer Institute (NCI). The NCI provides funding for both individual and institutional predoctoral and postdoctoral training grants with the intent to develop individuals with long-term commitment to

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cancer research. The following recommendations for training of Ph.D. students in cancer biology represent the deliberations and consensus of a working group of cancer biology chairs and program directors that represent more than 50 academic medical centers.

Part I: Foundation Courses

The following subjects are considered prerequisites for training in cancer biology. These may be satisfied prior to entry into a cancer biology program or during the first year of graduate study as individual courses or as part of a core curriculum.

- Genetics
- Cell and Molecular Biology
- Biochemistry
- Experimental Design/Biostatistics
- Ethics

Part II: Essential Elements of Training in Cancer Biology

A1. Training in Basic Science of Cancer Biology

Students need to be exposed to a discipline that emphasizes cancer in the context of human disease. A cancer biology curriculum should provide significant exposure to the core areas of cancer training listed below. How these topics are divided into courses is left to the individual training programs.

- Dysregulation of Signal Transduction Pathways
- Oncogenes and Tumor Suppressor Genes
- Control of Cell Proliferation, Cell Cycle, and Cell Death
- Carcinogenesis, DNA Damage, and Repair
- Tumor Angiogenesis, Invasion, and Metastases
- Cancer Virology
- Histopathology of Neoplasia
- Tumor Microenvironment and Stromal Interaction
- Cancer Genetics and Epigenetics
- Cancer Immunology
- *In vitro* and *In vivo* Tumor Models
- Cancer Stem Cells

A2. Training in the Translational Science of Cancer Biology

A unique aspect of training in cancer biology is the focus on human cancer. Therefore, in addition to these basic topics in

cancer biology, a cancer biology training program should provide exposure to the following topics that provide a bridge between the fundamental biology of cancer and clinical cancer. Core elements of this bench to bedside (and vice versa) training would include

- Molecular diagnosis and prognosis, including unbiased approaches to discovery using genomic, proteomic, and metabolomic analyses
- Molecular imaging
- Systems biology and bioinformatics
- Bioenergetics, endocrinology, and nutrition, as they are altered in cancer
- Therapeutic strategies: targeted and cytotoxic therapies including immunotherapy, hormone therapy, small molecules, proteins, RNA interference, etc. and
- Chemoprevention

A3. Training through Exposure to the Problems of Human Cancer

Interaction of cancer biology trainees with clinicians is encouraged and might take one or more of the following forms:

- Student attendance at tumor boards. A student would choose one particular cancer that they are interested in studying and attend an interdisciplinary tumor board to understand the clinical presentation of the disease, diagnostic and imaging tests, as well as patterns of cancer dissemination and the clinical management of the cancer.
- Observing cancer clinicians manage patients. A student may “shadow” an oncologist in their management of specific cancer patients. An alternative possibility is matching a graduate student with an oncology fellow/resident as they develop and present cases to attending physicians.
- Clinical trial team experience. A student may be involved in the development of a cancer clinical trial with a correlative component. The student might help with background and introductory materials, for example. This would provide the student insight into how a therapeutic is developed and provide experience in a multidisciplinary team approach to translational research.

Some graduate programs are not associated with medical schools. In this case, graduate students should rely on a combination of invited speakers, local medical centers, and support groups for cancer patients and their families.

B. The Laboratory Research Experience in Cancer Biology

- Rotations. Students are encouraged to experience at least three research rotations, thus exposing the students to different aspects of cancer biology, regardless of when they decide on their primary laboratory mentor. Multiple rotations foster learning of multiple approaches to solving complex biological problems, as well as mastering additional techniques.
- Thesis Research. No matter how basic the research thesis, it should address an important scientific issue that the student can understand and articulate as a problem in cancer biology. Cancer biology research is defined as any research investigating

the molecular, cellular, and organismal basis of tumors, then prevention, detection, and treatment.

- Advancement to Candidacy. There are many variations of the preliminary examinations. However, three components that are recommended as a part of the examination are (a) a written proposal in the form of an abbreviated “NIH-style” grant on a defined problem in cancer biology that the student proposes to study; (b) an oral presentation and defense of that proposal; and (c) demonstration of general knowledge of cancer biology.
- Dissertation Research Advisory Committee. The faculty preceptor that will advise the student on their thesis research must be conducting cancer-related research as defined above. In cases where the principal laboratory preceptor is not a member of the thesis advisory committee, at least one member should have a cancer-related research focus. Additionally, in certain circumstances, it might be useful to have a physician on a thesis committee to provide clinical insight into the thesis question. The Consortium recommends that the meetings of this committee should be held at least once a year, and at the end of these meetings progress should be assessed and reported to the mentor and student formally.

Part III: Other Research-Related Experiences in Cancer Biology

In addition to formal course work and research training, a fully developed program should provide exposure to advances in the discipline as a whole:

- Research Presentations. An essential element of training for students should be an opportunity to present their ongoing research at institutional, national, and/or international cancer meetings at least yearly.
- Journal Clubs. Journal clubs are an essential element of student training. They provide needed exposure to new research methodologies and their application to specific cancer problems; hone critical thinking; enhance communication skills; and provide lifelong tools for keeping current in cancer research.
- Seminar Speakers. Seminars provide students with the opportunities to interact with leaders in the cancer field. Every effort should be made to have both local and external speakers, and to have the students host and meet with speakers before or after the formal seminar. Such meetings provide an opportunity for students to obtain career counseling from invited speakers.
- Training Courses. Courses that allow for intensive investigation of a particular subject matter, often requiring immersion in a topic for several weeks or months, can complement education at the student’s home institution. These courses can be particularly valuable if knowledge on a certain technique or topic is limited at the student’s institution. Examples of such intensive study are the courses given at Woods Hole, the Jackson Lab, the AACR, or Cold Spring Harbor.
- Teaching Cancer Biology. A teaching experience for graduate students in which the student lectures on a topic in cancer biology is highly encouraged. This experience could be fulfilled by serving as teaching assistants for graduate or undergraduate classes in cancer biology or cancer-related courses.

Summary

Cancer biology is a young field. The science continues to evolve rapidly. Students now identify the field of cancer biology as a primary area of lifelong learning and research; they often make this career choice early in their scientific training. The goal of the Cancer Biology Training Consortium is to promote consistent, high-quality training for this new generation of cancer biologists. This curriculum for these students recommended here is based on a consensus of viewpoints of cancer biology educators throughout the United

States, and provides the framework for training in this distinct scientific discipline.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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