SUMMARY STATEMENT

PROGRAM CONTACT:
Mark Damico
240-276-5630
damicomw@mail.nih.gov

(Privileged Communication)

Release Date: **03/19/2015**

Application Number: **1 F30 CA199947-01**

Beckwitt, Colin Henry
University of Pittsburgh
3550 Terrace Street
S723 Scaife Hall
Pittsburgh, PA 15213-2500

Review Group: **ZRG1 F09B-B (20)**
Center for Scientific Review Special Emphasis Panel
Fellowships: Oncological Sciences

Meeting Date: **03/02/2015**
Council: **MAY 2015** ***PCC:*** **6OTR**
Requested Start:

Dual IC(s): **EB**

Project Title: **Oxygen impact on tumor metastasis dormancy and therapy**

Requested: **5 years**

Sponsor: **Wells, Alan**
Department: **Pathology**
Organization: **UNIVERSITY OF PITTSBURGH AT PITTSBURGH**
City, State: **PITTSBURGH PENNSYLVANIA**

SRG Action: **Impact Score: 36 Percentile: 31**
Next Steps: **Visit http://grants.nih.gov/grants/next_steps.htm**
Human Subjects: **44-Human subjects involved - SRG concerns**
Animal Subjects: **10-No live vertebrate animals involved for competing appl.**
NIH Defined Phase III Clinical trial

BUDGET MODIFICATIONS

1F30CA199947-01 Beckwitt, Colin

Protections for Human Subjects:
Budget and Period of Support:
SCIENTIFIC REVIEW OFFICER'S NOTES

RESUME AND SUMMARY OF DISCUSSION: This dual-degree fellowship application submitted by Colin Beckwitt proposes to investigate how oxygen tension contributes to the dormancy of metastatic breast cancer cells using a microphysiological system (MPS). The applicant is a talented student with a strong academic record. The outstanding sponsor has a strong mentoring record and extramural funding for the proposed research. However, there was a minor concern that the sponsor's funding period would be coming to an end soon. The panel considered the research training plan to address an important question, using unique technology. Therefore this application shows high training potential. Major negative score driving concerns were identified in the research training plan. Details related to how the data generated in the MPS would be analyzed were missing, there was no mention of statistical analysis, how cell type would be controlled for was not clear and essential information since the proposal uses a heterogeneous cell line and primary samples and there were no controls for the proposed cell marker analysis. Thus, while the applicant, mentor, environment and question were considered outstanding, major concerns with data analysis and MPS controls drove the panel to conclude this application has a very good training potential. Overall, the panel concluded that, if funded, this application would have a medium impact on the future scientific career of Mr. Beckwitt.

DESCRIPTION (provided by applicant): Following dissemination from a primary lesion, a few surviving carcinoma cells establish residency in distant sites (micrometastases). Many micrometastases assume a dormant (quiescent) cellular phenotype, characterized by a G0/G1 arrest that may persist years to decades before outgrowth to form clinically evident metastases; these emergent tumors almost inexorably lead to death. Unfortunately, micrometastases often appear to be refractory to therapeutic agents, even ones that show success against the primary tumors from which they derive. This situation is particularly daunting in breast cancer that can lie dormant for a decade or more before recurring. Signals from the tumor microenvironment have been shown to play a critical role in maintaining this dormant phenotype on the one hand or facilitating emergence from cellular quiescence on the other. Culture of breast cancer cell lines in a novel all human liver microphysiological system (MPS) our lab employs has been shown to reliably induce cancer cell dormancy. Traditionally, rapidly proliferating cancer cells resort to glycolysis in order to accumulate the massive amounts of metabolic intermediates required for cell division ("Warburg Effect"). However, the phenotypically dormant cancer cells may exhibit a different metabolic profile, which may be essential to both maintaining quiescence and successful novel treatment approaches. Our foundational model is that dormant micrometastases adapt a low metabolic and proliferative state concordant with chemoresistance and reduced glycolytic flux. We hypothesize that oxygen tension levels will dictate the switch between oxidative phosphorylation and glycolytic metabolism, and thereby impinge on dormancy. This model will be tested by measuring the basal glycolytic and oxidative phosphorylation fluxes of dormant cancer cells by quantifying glucose uptake, glycolytic enzyme expression, and intracellular ATP concentration through cell culture experiments and immunofluorescence. A novel hemoglobin-based oxygen carrier (HBOC) will be introduced to the system to modulate the oxygen tension to which the cancer cells and liver tissue are exposed. Sensitive ruthenium oxygen sensors will be used to determine the oxygen tension to which the cells are exposed and the trans-tissue oxygen gradient. The impacts of oxygen tension on tumor dormancy phenotype and cell metabolism will be determined. Finally, select anti-tumor agents, including the chemo- therapeutics doxorubicin and cisplatin, will be incorporated into the liver MPS to determine whether therapeutic efficacy is dependent on cancer cell metabolic state and additionally monitor toxicities to the liver tissue. Understanding the influence of oxygen tension on dormant micrometastasis phenotype, metabolism, and treatment

susceptibility is expected to yield insights into basic tumor biology and promote translational studies into improving the efficacy of current treatments (drug rescue) and the discovery of novel therapies.
PUBLIC HEALTH RELEVANCE: Tumor metastasis to the liver, one of the most common manifestations of advanced cancers, commonly establishes dormant, treatment refractory micrometastases and that herald mortality from the disease. The metabolic activity of these dormant tumor cells will be studied along with the impact of altering the oxygen tension of the tumor microenvironment on cancer cell metabolism, dormancy phenotype, and treatment potentiation. Understanding these processes will provide novel insights into the basic tumor biology of metastases, promote translational studies into improving the efficacy of existing agents (drug rescue), and motivate the development of new adjuvant therapies for this mortal stage of cancer progression.

CRITIQUE 1:

Fellowship Applicant: 1
Sponsors, Collaborators, and Consultants: 1
Research Training Plan: 5
Training Potential: 4
Institutional Environment & Commitment to Training: 2

Overall Impact: This application is from a highly competitive applicant who graduated from MIT with a 4.95 GPA in biological engineering. His letters of recommendation describe an outstanding, highly motivated and talented student. His sponsor at U Pitt has extensive training experience including 5 previous MD/PhD students. He is extremely well published. The sponsor's interests and his collaborations should provide an ideal environment, highly conducive for the success of the research project, which is novel and challenging. The project will utilize a novel liver microphysiological system that will be seeded with breast cancer cells to investigate the role of oxygen tension on the switch between dormancy and progression of liver micrometastases. The project is very innovative but there is concern about how data will be analyzed due to effects of various agents on 2 systems: both liver and tumor cells. The impact of the training program in preparing the applicant for leadership in oncological sciences is judged to be modest.

1. Fellowship Applicant:

Strengths

- Outstanding academic record and background
- Undergraduate degree in biological engineering from MIT
- Very enthusiastic letters of support
- Strong interest in cancer metastasis
- Co-author on 2 manuscripts

Weaknesses

- None

2. Sponsors, Collaborators, and Consultants:

Strengths

- Sponsor has extensive training experience including 5 prior MD/PhD students
- Leader in a UH3 award to develop a microfluidic organotypic liver bioreactor that mimics the human situation to test the behavior of tumor micrometastases.

- Other collaborators in the multidiscipline team include biological engineers, imagers, pharmacologists and a transplant surgeon
- Sponsor has an outstanding publication record.
- Adequate funding

Weaknesses

- None

3. Research Training Plan:

Strengths

- The training plan well thought out and suitably tailored to the interests and needs of this student.
- The research topic is a challenging one and based on previous accomplishments of this group the research experience will be high quality.
- Use of the LiverChip system
- Use of novel oxygen carriers

Weaknesses

- There is no statistics section and no details of how data will be analyzed. This is particularly important because the plan is to examine effects on 2 systems: the tumor cells and the liver system, e.g. the statins would be expected to have a major impact on the liver cell lipid metabolism so how will this in turn affect the tumor cells.
- The Research Training Plan is written in such a descriptive and superficial manner that it lacks experimental detail. Thus, it is often hard to tell what comparisons will be made.
- Detection levels in the system that is measuring various parameters in dormant cells are not clear.

4. Training Potential:

Strengths

- This project has the potential to provide a sound foundation in research for a physician scientist

Weaknesses

- None

5. Institutional Environment & Commitment to Training:

Strengths

- Excellent commitment to training physician scientists at University of Pittsburg

Weaknesses

- None

Protections for Human Subjects:

Not Applicable (No Human Subjects)

Vertebrate Animals:

Not Applicable (No Vertebrate Animals)

Biohazards:

Not Applicable

Training in the Responsible Conduct of Research:

Comments on Format (Required):

- on-line and face to face

Comments on Subject Matter (Required):

- comprehensive

Comments on Faculty Participation (Required):

- faculty lectures + workshops

Comments on Duration (Required):

- 2hrs +2hrs

Comments on Frequency (Required):

- 4 times/year + 2 times/year

Select Agents:

Not Applicable (No Select Agents)

Resource Sharing Plans:

Unacceptable

- not addressed

Budget and Period of Support:

Recommended budget modifications:

- Reduce time

CRITIQUE 2:

Fellowship Applicant: 1
Sponsors, Collaborators, and Consultants: 1
Research Training Plan: 2
Training Potential: 2
Institutional Environment & Commitment to Training: 1

Overall Impact: This is an application from an outstanding student and sponsor. The project will investigate an important aspect of tumor metastasis in the liver – metabolism, dormancy, and sensitivity to oxygen. The experimental design will provide an excellent learning opportunity for the student; however, some aspects of liver physiology should be considered when drawing conclusions from the

proposed model. The intrinsic high vascularity of this organ and its ability to remodel its matrix and accumulate lipid adds complexity to the mechanisms controlling tumor metastasis in the liver.

1. Fellowship Applicant:

Strengths

- B.S., Bioengineering, MIT (2013) – exceptional academic record
- Academic honors, engineering recognition award
- Two publications (one in revision; second and third author)
- Letters of recommendation – extremely strong

Weaknesses

- None

2. Sponsors, Collaborators, and Consultants:

Strengths

- Exceptional physician-scientist sponsor who is well-funded with a strong history of training students
- Broad range of expertise and active research projects which includes cancer signaling, cell motility assessment, and developing and testing of an organotypic liver bioreactor (collaboration with MIT)

Weaknesses

- None

3. Research Training Plan:

Strengths

- Interesting and important area of investigation – better understanding of tumor metastasis in the liver
- Opportunity to gain experience in a range of techniques

Weaknesses

- It would be helpful to include a discussion about oxygen in the setting of a highly vascularized organ such as the liver. The liver has an elaborate network of sinusoidal endothelial cells and muscularized vasculature within the portal tract. How does the parenchyma of the liver remodel under a change in oxygen status?
- The hepatocyte and stellate cells have the capacity to store significant amounts of lipid. Lipid can serve as an energy source. This alternative energy source to fuel proliferation should be discussed.

4. Training Potential:

Strengths

- High training potential – excellent student and exceptional sponsor

5. Institutional Environment & Commitment to Training:

Strengths

- Exceptional environment

Weaknesses

- None

Protections for Human Subjects:

Unacceptable Risks and/or Inadequate Protections

- more details are needed to determine exemption status

Vertebrate Animals:

Not Applicable (No Vertebrate Animals)

Biohazards:

Not Applicable

Training in the Responsible Conduct of Research:

Acceptable

Comments on Format (Required):

- lecture, small group

Comments on Subject Matter (Required):

- ethics, human subjects, data management, authorship, others

Comments on Faculty Participation (Required):

- faculty participation mentioned

Comments on Duration (Required):

- 15 weeks

Comments on Frequency (Required):

- two hours per week

Select Agents:

Not Applicable (No Select Agents)

Resource Sharing Plans:

Acceptable

Budget and Period of Support:

Recommended budget modifications:

- Reduce time to four years; reduce total budget by $200,000

CRITIQUE 3:

Fellowship Applicant: 1
Sponsors, Collaborators, and Consultants: 1
Research Training Plan: 2
Training Potential: 1
Institutional Environment & Commitment to Training: 1

Overall Impact: This is a F30 application from a MSTP candidate from the University of Pittsburgh, who has outstanding scholastic and research credentials. This application is focused on investigating the molecular basis for tumor cell dormancy, especially in breast cancer cells, using the LiverChip microphysiological system. The complex process of tumor cell dormancy is reduced into a fundamental hypothesis based on some previous studies that the cells that resort to dormant micrometastases "adapt a low metabolic and proliferative state concordant with chemoresistance and reduced glycolytic flux" and the "oxygen tension levels will dictate the switch between oxidative phosphorylation and glycolytic metabolism, and impact dormancy and chemoresponsiveness" The hypothesis will be tested on the LiverChip system that will mimic liver metastases often encountered in breast cancer recurrence. Using this system, the applicant will test whether 1) dormant cancer cells display decreased levels of glycolytic flux, 2) different oxygen levels affect tumor cell dormancy, and 3) select anti-tumor agents are dependent on tumor cellular metabolic state/tissue oxygen capacity. The results could provide novel insights into the mechanism of tumor cell dormancy and reactivation. This is a great strength of the application. Additional strengths include the strong track record of the sponsor and the assembled multi-institutional collaborators. The sponsor has expertise as well as adequate funding to support the proposed studies. A perceived weakness is overambitious breadth of the project.

1. Fellowship Applicant:

Strengths

- The scholastic record of the applicant is quite strong. His near perfect at MIT (4.9/5.0) in biological engineering is a great strength for the proposed interdisciplinary studies.
- Co-authored one publication from the undergraduate studies at MIT. A coauthored manuscript based on his rotation studies is under revision.
- The applicant's articulation of his interests and career goals.
- Strong recommendation letters places him at the top 5 %. One letter places him in the top 2-3 % of undergraduates at MIT. Truly outstanding candidate.

Weaknesses

- None

2. Sponsors, Collaborators, and Consultants:

Strengths

- The track record of the sponsor Dr. Alan Wells in mentoring pre-doctoral, postdoctoral, and MD/PhD students is outstanding (22 pre-doctoral trainees, 16 postdoctoral fellows including 5 MD/PhD students) with a successful placement record.
- Research facilities available appear to be sufficient for the proposed project.

- As stated by the mentor, the outstanding team of collaborators involved in the LiverChip project who will be interacting with the applicant includes Donna Stolz and Catherin Baty of U Pittsburgh as well as Dr. Linda Griffith and Dr. Lauffenburger at MIT.

Weaknesses

- None

3. Research Training Plan:

Strengths

- The hypothesis and the rationale for the hypothesis are presented well.
- The applicant should be able to test the proposed hypothesis using the LiverChip model.
- The proposed research appears to be highly appropriate for the candidate's interest and former undergraduate training and it could enhance the research potential to a great extent.
- The strategies proposed appropriate for the proposed studies.

Weaknesses

- Somewhat high-risk high-gain project for the proposed research training.

4. Training Potential:

Strengths

- The proposed research could augment the applicant's research capabilities and expertise further.
- Highly enthusiastic statements on the applicant's research potential by the former mentors provide additional strength.
- The proposed mentoring plan to enhance training potential is outstanding.
- Well-articulated structured mentoring plan is strength.

Weaknesses

- None

5. Institutional Environment & Commitment to Training:

Strengths

- Outstanding support to mentoring and research training as evidenced by the presentation of structured mentoring plan.
- University of Pittsburgh has all appropriate research infrastructure for the proposed studies.

Weaknesses

- None

Protections for Human Subjects:

Not Applicable (No Human Subjects)

- The proposal uses established human cell lines and does not involve human subjects.

Vertebrate Animals:

Not Applicable (No Vertebrate Animals)

Biohazards:

Acceptable

Training in the Responsible Conduct of Research:

Acceptable

Budget and Period of Support:

Recommended budget modifications or possible overlap identified:

- Reduce time

THE FOLLOWING SECTIONS WERE PREPARED BY THE SCIENTIFIC REVIEW OFFICER TO SUMMARIZE THE OUTCOME OF DISCUSSIONS OF THE REVIEW COMMITTEE, OR REVIEWER'S WRITTEN CRITIQUES, ON THE FOLLOWING ISSUES:

PROTECTION OF HUMAN SUBJECTS (Resume): UNACCEPTABLE
An E4 exemption was claimed but lacked documentation.

COMMITTEE BUDGET RECOMMENDATIONS: Recommended budget modifications

- **Reduce time to 4 years**

SCIENTIFIC REVIEW OFFICER'S NOTES:
Sufficient documentation was not provided for the reviewers to determine if there were human samples or human subjects proposed in this study. Human subjects would require an E4 exemption but human samples might not be considered for protection. Details are needed to make this distinction. Since the reviewers could not clearly determine the reason for the E4 exemption, human subjects status is considered to be a concern for this application.

NIH has modified its policy regarding the receipt of resubmissions (amended applications). See Guide Notice NOT-OD-14-074 at http://grants.nih.gov/grants/guide/notice-files/NOT-OD-14-074.html. The impact/priority score is calculated after discussion of an application by averaging the overall scores (1-9) given by all voting reviewers on the committee and multiplying by 10. The criterion scores are submitted prior to the meeting by the individual reviewers assigned to an application, and are not discussed specifically at the review meeting or calculated into the overall impact score. Some applications also receive a percentile ranking. For details on the review process, see http://grants.nih.gov/grants/peer_review_process.htm#scoring.

MEETING ROSTER

Center for Scientific Review Special Emphasis Panel
CENTER FOR SCIENTIFIC REVIEW
Fellowships: Oncological Sciences
ZRG1 F09B-B (20) L
March 02, 2015 - March 03, 2015

CHAIRPERSON

BOGLER, OLIVER , PHD
PROFESSOR
SENIOR VICE PRESIDENT FOR ACADEMIC AFFAIRS
DEPARTMENT OF NEUROSURGERY
DIVISION OF SURGERY
UNIVERSITY OF TEXAS MD ANDERSON CANCER CENTER
HOUSTON, TX 77030

MEMBERS

BASTIAN, BORIS C, MD
GERSON AND BARBARA BAKAR DISTINGUISHED
PROFESSOR OF CANCER BIOLOGY
DEPARTMENT OF DERMATOLOGY AND PATHOLOGY
UNIVERSITY OF CALIFORNIA SAN FRANCISCO
SAN FRANCISCO, CA 94143

CHINNI, SREENIVASA R, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF UROLOGY
WAYNE STATE UNIVERSITY
DETROIT, MI 48201

CORRY, PETER M, PHD
DISTINGUISHED PROFESSOR
DEPARTMENT OF RADIATION ONCOLOGY
UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES
LITTLE ROCK, AR 72205

CRAWFORD, SUSAN E, MD
PROFESSOR- VICE CHAIR FOR RESEARCH
DEPARTMENT OF PATHOLOGY
SAINT LOUIS UNIVERSITY SCHOOL OF MEDICINE
ST. LOUIS, MO 63104

CRESS, ANNE E, PHD
PROFESSOR
DEPARTMENT OF CELLULAR & MOLECULAR MEDICINE
INTERIM DIRECTOR
UNIVERSITY OF ARIZONA CANCER CENTER
UNIVERSITY OF ARIZONA
TUCSON, AZ 85718

CUMMINGS, BRIAN S, PHD
ASSOCIATE PROFESSOR
PHARMACEUTICAL AND BIOMEDICAL SCIENCES
COLLEGE OF PHARMACY
UNIVERSITY OF GEORGIA
ATHENS, GA 30602

DELONG, ROBERT K, PHD
ASSOCIATE PROFESSOR
NANOTECHNOLOGY INNOVATION CENTER
KANSAS STATE UNIVERSITY
MANHATTAN, KS 66506

DERYNCK, RIK M, PHD
PROFESSOR
DEPARTMENT OF CELL AND TISSUE BIOLOGY
UNIVERSITY OF CALIFORNIA, SAN FRANCISCO
SAN FRANCISCO, CA 94143

DHANASEKARAN, DANNY N, PHD
PROFESSOR
DEPUTY DIRECTOR FOR BASIC RESEARCH
STEPHENSON OKLAHOMA CANCER CENTER
UNIVERSITY OF OKLAHOMA HEALTH SCIENCES CENTER
OKLAHOMA CITY, OK 73104

DUHE, ROY J, PHD
PROFESSOR
DEPARTMENT OF PHARMACOLOGY AND TOXICOLOGY
AND DEPARTMENT OF RADIATION ONCOLOGY
ASSOCIATE DIRECTOR FOR CANCER EDUCATION
UNIVERSITY OF MISSISSIPPI MEDICAL CENTER
JACKSON, MS 392164505

EDWARDS, IRIS J, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF PATHOLOGY
WAKE FOREST UNIVERSITY
WINSTON-SALEM, NC 27157

EGILMEZ, NEJAT K, PHD
PROFESSOR AND CHAIR
DEPARTMENT OF MICROBIOLOGY AND IMMUNOLOGY
UNIVERSITY OF LOUISVILLE SCHOOL OF MEDICINE
LOUISVILLE, KY 40202

FRASOR, JONNA , PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF PHYSIOLOGY AND BIOPHYSICS
UNIVERSITY OF ILLINOIS AT CHICAGO
CHICAGO, IL 60612

HATHAWAY, HELEN J, PHD
PROFESSOR
DEPARTMENT OF CELL BIOLOGY AND PHYSIOLOGY
UNIVERSITY OF NEW MEXICO SCHOOL OF MEDICINE
ALBUQUERQUE, NM 87131

HUANG, ALEX YEE-CHEN, MD, PHD
CASE WESTERN RESERVE UNIVERSITY SCHOOL OF
MEDICINE
ASSOCIATE PROFESSOR
DEPARTMENT OF PEDIATRICS
CLEVELAND, OH 441067288

HUDIG, DOROTHY , PHD
PROFESSOR
DEPARTMENT OF MICROBIOLOGY AND IMMUNOLOGY
UNIVERSITY OF NEVADA
RENO, NV 89557

KNUDSON, CHARLES MICHAEL, MD, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF PATHOLOGY
UNIVERSITY OF IOWA
IOWA CITY, IA 52242

KOLESAR, JILL MARIE, PHAR
PROFESSOR
COMPREHENSIVE CANCER CENTER
UNIVERSITY OF WISCONSIN
MADISON, WI 53792

LI, BENYI , MD, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF UROLOGY
UNIVERSITY OF KANSAS MEDICAL CENTER
KANSAS CITY, KS 66160

LI, KAIYI , PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF SURGERY
BAYLOR COLLEGE OF MEDICINE
HOUSTON, TX 77030

MALEK, SAMI NIMER, MD
ASSOCIATE PROFESSOR
UNIVERSITY OF MICHIGAN AT ANN ARBOR
ANN ARBOR,, MI 481091274

MEDINA-KAUWE, LALI K, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF BIOMEDICAL SCIENCES
CEDARS-SINAI MEDICAL CENTER
LOS ANGELES, CA 90048

MERCOLA, DAN , MD, PHD
PROFESSOR
DEPARTMENT OF MEDICAL SCIENCES
UNIVERSITY OF CALIFORNIA AT IRVINE
IRVINE, CA 92696

MILLER, KATHY D, MD
ASSOCIATE PROFESSOR
DEPARTMENT OF MEDICINE
DIVISION OF HEMATOLOGY/ONCOLOGY
INDIANA UNIVERSITY SIMON CANCER CENTER
INDIANA UNIVERSITY
INDIANAPOLIS, IN 46202

NABORS, LOUIS B III, MD
PROFESSOR AND DIRECTOR
DIVISION OF NEURO-ONCOLOGY
DEPARTMENT OF NEUROLOGY
UNIVERSITY OF ALABAMA AT BIRMINGHAM
BIRMINGHAM, AL 35294

NEWFELD, STUART J, PHD
PROFESSOR AND FACULTY LEADER
CELLULAR AND MOLECULAR BIOSCIENCES
SCHOOL OF LIFE SCIENCES
ARIZONA STATE UNIVERSITY
TEMPE, AZ 85287

PORCU, PIERLUIGI , MD
ASSOCIATE PROFESSOR
DIVISION OF HEMATOLOGY
THE OHIO STATE UNIVERSITY
COLUMBUS, OH 43210

RATHMELL, WENDY KIMRYN, MD, PHD
ASSOCIATE PROFESSOR
HEMATOLOGY AND ONCOLOGY DIVISION
DEPARTMENT OF MEDICINE AND GENETICS
LINEBERGER COMPREHENSIVE CANCER CENTER
UNIVERSITY OF NORTH CAROLINA CHAPEL HILL
CHAPEL HILL, NC 27599

RUBIN, JOSHUA B, MD, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF PEDIATRICS
WASHINGTON UNIVERSITY
ST LOUIS, MO 63110

SCHWARTZ, JEFFREY L, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF RADIATION ONCOLOGY
UNIVERSITY OF WASHINGTON
SEATTLE, WA 98195

SHANKER, ANIL , PHD
ASSOCIATE PROFESSOR
DEPARTMENT BIOCHEMISTRY AND CANCER BIOLOGY
MEHARRY MEDICAL COLLEGE
NASHVILLE, TN 615327646

WEBB, DONNA J, PHD
ASSOCIATE PROFESSOR
DEPARTMENT OF BIOLOGICAL SCIENCES
VANDERBILT UNIVERSITY
NASHVILLE, TN 37232

XU, X NANCY , PHD
PROFESSOR
DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY
OLD DOMINION UNIVERSITY
NORFOLK, VA 23529

ZHU, TIMOTHY C, PHD
PROFESSOR
DEPARTMENT OF RADIATION ONCOLOGY
UNIVERSITY OF PENNSYLVANIA SCHOOL OF MEDICINE
PHILADELPHIA, PA 19104

MAIL REVIEWER(S)

MILLER, JOSHUA WILLIAM, PHD
PROFESSOR AND CHAIR
DEPARTMENT OF NUTRITIONAL SCIENCES
RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY
NEW BRUNSWICK, NJ 08901

O'KEEFE, BARRY R, PHD
STAFF SCIENTIST
NCI- FREDERICK
FREDERICK, MD 21702

SCIENTIFIC REVIEW OFFICER

HOWARD, OLA MAE ZACK, PHD
SCIENTIFIC REVIEW OFFICER
CENTER FOR SCIENTIFIC REVIEW
NATIONAL INSTITUTES OF HEALTH
BETHESDA, MD 20892

EXTRAMURAL SUPPORT ASSISTANT

PAYNE, OMAR
EXTRAMURAL SUPPORT ASSISTANT
NATIONAL INSTITUTE OF HEALTH
CENTER FOR SCIENTIFIC REVIEW
BETHESDA, MD 20892

Consultants are required to absent themselves from the room during the review of any application if their presence would constitute or appear to constitute a conflict of interest.