

**Proposal for Joint Sponsorship of the PhD in Integrated Biology and  
Medicine (IBM) at Duke-NUS Graduate Medical School  
by Duke University and National University of Singapore**

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## **Executive Summary**

This proposal seeks the joint sponsorship and awarding of the PhD degree in Integrated Biology and Medicine (IBM) at Duke-NUS by Duke University and National University of Singapore. Duke-NUS is a graduate medical school and biomedical research institution established by faculty of Duke School of Medicine and financed by the government of Singapore. It is an academic component of NUS. Duke and NUS already sponsor the very successful joint MD degree at Duke-NUS. We propose that the PhD degree be similarly jointly sponsored. The PhD degree program has already been in operation for five years, the first dozen students having graduated from NUS. The IBM student admissions metrics thus far are very similar to those of Duke PhD programs overall, in terms of GRE, undergraduate GPA, English proficiency scores, prior research background, etc, though the applicant pool is primarily Singaporean and Southeast Asian. The proposed program is closely modeled on Duke biomedical PhD programs, and students will be held to the same requirements and standards as PhD students in Duke Graduate School. The parameters of the joint sponsorship will comply with the requirements of Duke's SACS accreditors. Many faculty at Duke-NUS also have faculty appointments at Duke; additional measures are in place to ensure a strong, active and continual Duke presence in the research and curricular aspects of the program. Oversight will be provided by a committee composed of senior faculty administrators of Duke Graduate School and School of Medicine, as well as NUS. The program has no direct financial cost to Duke University, yet opens new research avenues to Duke and strengthens Duke's presence in Asia.

## **Background and Rationale for Joint Degree**

Duke-NUS is celebrating the 10-year anniversary of its founding, a time span in which the school has grown into a successful and prominent center for biomedical science research and medical and graduate education in Asia.

NUS is a high profile university, consistently recognized as one of the top three universities in Asia and top 50 in the world. The joint venture initiated in 2005 between Duke University School of Medicine in partnership with the National University of Singapore (NUS) resulted in the establishment of Duke-NUS Graduate Medical School. In 2009 Duke-NUS opened the doors of its new state-of-the art medical and graduate school research building, built and financed by the government of Singapore. Duke-NUS is solely owned and financed by the government of Singapore, and Duke University has no financial commitments to Duke-NUS.

The purpose of this application is to bring Duke-NUS's graduate program in Integrated Biology and Medicine (IBM), already sponsored by NUS, in greater alignment with Duke University's graduate programs in biomedical sciences through obtaining sponsorship of the IBM program by Duke University. This will result in the granting of a joint PhD degree between NUS and Duke University for graduating IBM students.

It is anticipated that the result of sponsorship by Duke University, along with the continued sponsorship of NUS, will increase ongoing training and collaborative opportunities for Duke-NUS, NUS and Duke University graduate students, faculty and other researchers. This in turn will leverage unique research expertise and facilities between the campuses, and enhance Duke University's presence in Asia and NUS's presence in the United States.

We strongly believe that an important and necessary step toward achieving these goals is to have a joint PhD program between Duke University and NUS. A similar joint degree (MD) already exists between Duke University Medical School and NUS at Duke-NUS Graduate Medical School for similar reasons. Aligning the PhD program in the same fashion is the next logical step in degree development at Duke-NUS and in further synergizing the global strengths of both universities.

Duke-NUS grew into a leading research institution under the leadership of Professor Pat Casey, Senior Vice Dean of Research at Duke-NUS and James Duke Professor of Pharmacology and Cancer Biology and of Biochemistry at Duke University. From its inception in 2005, Professor Pat Casey brought to Duke-NUS Duke University's high standards in medical and graduate education and a culture of "Dukeness". The Duke University graduate research culture was transplanted to Duke-NUS initially by recruitment of high-caliber tenure track research faculty from Duke. Subsequently, Duke-NUS expanded its recruitment to attract leading researchers from other renowned universities and research centers. To date, a total of 88 regular rank faculty have been recruited to Duke-NUS, attracting S\$290 million (US\$ 223 million) in competitive research funding from national and international sources. Over 2,000 papers have been published from Duke-NUS faculty and their students in top peer-reviewed journals such as Science, Nature, Cell, Nature Genetics, Nature Medicine, and PNAS. Our faculty have filed 51 international patents and initiated three clinical trials. These successes indicate that the quality of research and the research environment at Duke-NUS are of very high caliber, similar to that of Duke University.

Five world-class signature research programs (SRPs, equivalent to basic science departments at Duke School of Medicine) were established with a focus on diseases important to Singapore and Southeast Asia (Table 1, page 3). These areas have been chosen due to their relevance to major health burdens of Singapore and the region, and to their alignment with major research interests of Duke faculty.

The first dean of Duke-NUS was Professor Ranga Krishnan of Duke University. Like Professor Pat Casey, Dean Ranga, from the very beginning, instilled a sense of Duke University's culture to Duke-NUS that has been solidified over the last 10 years. Dean Ranga's recent successor is Professor Tom Coffman, a renowned clinician and researcher from Duke University, thus maintaining continuity of our programs with Duke University and its culture.

Since the inception of the partnership between Duke and NUS in 2005, Duke-NUS has made great progress toward building an internationally strong reputation for its biomedical research and innovative education. A joint degree between Duke and NUS for the IBM PhD program would be a recognition of this excellence, and an additional reflection of the successful relationship between Duke University and NUS.

#### *Medical and Graduate Education at Duke-NUS*

The goal for Duke-NUS was to establish a top-notch American style medical school in Singapore. The first cohort of medical students matriculated in 2007 and thus far five classes of medical students have graduated. Our medical students graduate with the Doctor of Medicine (MD) degree jointly awarded between Duke and NUS.

Similar to Duke University, Duke-NUS strongly believes that having a strong PhD program in basic and biomedical sciences is instrumental in creating a research-driven environment that is vital to training the next generation of scientists and physician scientists. To achieve this goal, Duke-NUS aimed at starting the first American-style PhD research degree program in Singapore. The IBM PhD program was approved by NUS in June 2009 (for implementation in AY2010/11). Following approval by NUS, the Duke-NUS program in Integrated Biology and Medicine (IBM) program was established as a rigorous, full-time PhD program with milestones comparable to those established for PhD programs at Duke University and NUS. The goal is to provide a high-caliber training program for clinician-scientists and biomedical PhDs to help meet the demand of developing and training scientists for Singapore's growing biomedical sector.

The first class of PhD students matriculated in 2010, and eleven of our students from this first cohort have successfully defended their dissertations. Duke-NUS medical students also have the option to join the PhD Program after completion of their first two years in medical school. Thus, the Duke-NUS program in Integrated Biology and Medicine (IBM) trains MD/PhD as well as PhD students.

We strongly feel that formally aligning the IBM doctoral program with Duke University would provide major advantages to training the best and brightest medical and PhD students in Singapore, and provide tangible benefits to both Duke University and NUS.

A few key points on the benefits of a joint degree are summarized here. These will be expanded on in the subsequent sections.

Duke-NUS is a vibrant partnership between Duke and the National University of Singapore (NUS). Since its inception 10 years ago, great accomplishments have been achieved. Duke-NUS education and research are top-notch and clearly grounded in many of Duke's principles. A joint medical doctor degree has been awarded since the first graduating class in 2011. A joint degree for the PhD program would be the natural complement to the joint MD.

The joint degree does not come with any financial cost to Duke University. The government of Singapore provides sufficient funding to Duke-NUS to support 75 PhD students, i.e. allowing matriculation of a class of at least 15 each year with support for 5 years each. This joint degree would further help Duke solidify its partner institution in Singapore as a major research hub for its outreach in Asia with no financial burden.

A joint degree will foster and provide additional opportunities for expanding research collaborations, student exchange programs and visiting fellowships between Duke and Singapore. This provides the Duke community with additional, high quality training and research opportunities in Asia, and similarly provides a contact point for NUS and Duke-NUS faculty and students in the United States.

A joint degree will also enhance the talent pool attracted to Duke-NUS; in particular, US and Asian students may be more attracted to a joint degree program. This will also benefit our faculty, and will strengthen our overall research and education program. With a PhD program more closely linked to Duke through a joint degree, our students may subsequently be attracted to Duke for post-doctoral training, and our faculty more likely to turn to Duke for collaborations.

In addition to IBM PhD students, numerous PhD students from graduate programs at NUS choose Duke-NUS faculty as their thesis mentors. These students, working in research laboratories at Duke-NUS, will also benefit from the expanded collaboration between Duke University and Duke-NUS. NUS students will have additional exposure to research collaborations and can take advantage of new exchange programs between the two campuses. One such recent program called "Pre-Doctoral and Post-doctoral Research Exchange Program: Duke and Duke-NUS Medical School Singapore Collaborative Research Initiative" allows IBM and NUS students working at Duke-NUS to spend a month in a Duke University lab. Together this provides the NUS community with access to supplementary research opportunities at Duke University and correspondingly provides the Duke community with additional, high quality training and research opportunities at NUS.

The doctoral degree at Duke-NUS is one of several PhD degrees offered by the National University of Singapore (NUS). However, the quality of Duke-NUS and Duke's graduate training are similar and more rigorous compared to PhD programs at NUS. Our training is based on US standards and in a research environment that is similar in quality to Duke University. A joint degree would allow our program to be more visibly distinguished relative to other programs in Singapore and Asia, in turn enhancing Duke-NUS's talent pool.

Duke-NUS, as a Research hub in Asia for Duke, provides more opportunities for collaboration in emerging research areas. The graduate program at Duke-NUS has unique components that are not present at Duke University that Duke could benefit significantly from through collaboration. These new areas include the Health Services and Systems Research Program as well as the Emerging Infectious Disease Program.

The goal is to increase ongoing training and collaborative opportunities for NUS, Duke-NUS and Duke University graduate students and professors, leverage on unique research expertise and facilities between the campuses, and enhance Duke University's presence in Southeast Asia.

## 1. Rationale for a joint degree

### PhD program in Integrative Biology and Medicine (IBM) was established in 2010

In 2000, the Singapore government launched the Biomedical Sciences Initiative aimed at making Singapore a biomedical research hub of Asia. At the same time, the Ministry of Education recommended for Singapore to establish a graduate medical school to educate highly trained physician-scientists needed to support the Biomedical Initiative. Two years later a Singapore delegation of leaders including the Deputy Prime Minister at the time, Dr. Tony Tan, visited Duke to discuss establishing such a school. The partnership between Duke and NUS was officially formalized in 2005, and in 2007 the first cohort of medical students was admitted. At the same time Duke-NUS recruited a high-caliber cadre of tenure track research faculty from Duke which would then lead to attracting other leading researchers from renown universities around the world. Because Duke-NUS is a small school relative to NUS, it set out to focus its research and graduate level training efforts into specific disease research areas rather than traditional academic departments. This design resulted in the establishment of five Signature Research Programs that gravitate around diseases important to Singapore and Southeast Asia (Table 1).

**Table 1.** Signature Research Programs (SRP) at Duke-NUS Graduate Medical School in Singapore.

Signature Research Program	Program Director
Cancer and Stem Cell Biology (CSCB)	Prof David Virshup
Cardiovascular and Metabolic Disorders (CVMD)	Prof Stuart Cook
Emerging Infectious Disease (EID)	Prof Linfa Wang
Health Services and Systems Research (HSSR)	Prof David Matcher
Neuroscience and Behavior Disorder (NBD)	A/Prof Hongyan Wang

To date a total of 88 regular rank faculty have been recruited into these Signature Research Programs attracting S\$290 million (US\$ 223 million) in competitive research money and publishing papers in peer-reviewed journals such as Nature, Science, Cell, Nature Genetics, Nature Medicine, and PNAS.

In 2010, the PhD program in Integrative Biology and Medicine (IBM) was approved by NUS and the Duke-NUS governing board with the aim to establish a high-caliber training program for physician-scientists and biomedical PhDs trained at Duke-NUS. The first 11 students matriculated in 2010, and the program has now expanded to 49 students. The first ten students successfully defended their dissertations and have graduated as of August 2015.

As mentioned, the IBM program trains both PhD and MD/PhD students. MD students enter the PhD program following completion of the first two years in medical school. After completing the PhD degree, MD/PhD students return to finish the fourth year of medical school, similar to the MSTP at Duke Medical School.

Currently, the IBM PhD degree is solely awarded by NUS. Duke-NUS strongly believes that awarding the joint PhD degree, as is done for the MD degree, will be mutually beneficial for both Duke University and NUS. Among the arguments for this are these points:

a) We have established a PhD program that is very similar in structure, student qualifications and faculty excellence to the Duke PhD programs in basic medical sciences. Expectations of student performance, milestones and accomplishments are similar to those in Duke biomedical science doctoral programs (Table 2).

**TABLE 2: Overview of milestones in the IBM PhD program**

Year in program	Milestones
Year 1	Coursework; Start of Thesis Research
Year 2	Completed coursework; Passing of PhD Qualifying Exam (PQE)
Years 3-5	Satisfactory research progress (evaluated by Thesis Advisory Committee & OGS) Dissertation writing and successful defense Publication of first author research paper

Further, students recruited to the program have a comparable educational background as students entering a doctoral program in biomedical sciences at Duke and similar metrics to those admitted to PhD programs throughout Duke Graduate School (Table 3).

**Table 3:** Qualifications of enrolled students in the IBM PhD program at Duke-NUS and comparison to Duke University doctoral program metrics.

Intake Year	2010/11	2011/12	2012/13	2013/14	2014/15
Enrolled (per year)	11	9	13	14	13
GRE (mean; range)	1398 (1310-1455)	1380 (1320-1440)	318 (312-325)	318 (309-328)	322 (312-333)
GPA(mean; range)	3.6 (3.1-3.8)	3.8 (3.2-4.0)	3.6 (3.2-3.9)	3.6 (3.0-3.9)	3.6 (3.1-4.0)
<i>Duke University (all PhD programs)</i>					
GRE (mean)	1337	1346	320	322	322
GPA (mean)	3.7	3.7	3.7	3.7	3.7

Importantly, the quality of the faculty at Duke-NUS is considered comparable to Duke faculty, and they are promoted and hired based on Duke standards (appendix for CVs of faculty in section 7). Furthermore, many of the faculty at Duke-NUS hold joint appointments at Duke (Table 4)

b) Our goal for the PhD program is to remain a rigorous, high-quality training program closely aligned with both Duke and NUS. To carry this out, we are developing an oversight committee composed of senior academic administrators and faculty members from NUS and Duke University (see page 26). The oversight committee will be charged with formal review of the program at set intervals and will also receive regular updates from the IBM program. In addition, the IBM has appointed a Duke faculty liaison who is active both at Duke and Duke-NUS to help ensure that Duke standards are understood and employed. Prof Soman Abraham, who is currently the Director of Graduate Studies in Pathology at Duke and is an researcher in the Emerging Infectious

Disease program at Duke-NUS, will provide advice to the IBM program's administration on continual improvements to the IBM graduate program. Prof Abraham will also serve on the oversight committee. Hence, Duke University together with NUS will be given a supervisory role of the Duke-NUS PhD program to ensure continued quality and alignment of the IBM program with Duke. Overall, regular review of the PhD program by Duke and NUS and the involvement of Professor Abraham, provides direct oversight of the PhD program, further contributing to strengthening the relationship between the two campuses.

c) The joint degree with Duke will enhance the recognition and visibility of the IBM PhD program. A raised profile of the IBM PhD program will in turn benefit student recruitment. The IBM program already attracts exceptional students, but a joint degree is expected to increase the application pool of talented students, in particular from the USA and parts of Asia. With a PhD program more closely linked to Duke, these talented students may consequently be attracted to Duke for post-doctoral training. Along similar lines, having exchange of students and postdoctoral research fellows between Duke and Duke-NUS can lead to new research collaborations between the two campuses.

d) Establishment of a joint PhD program will strengthen the presence of Duke graduate education and biomedical research in Asia without financial cost to Duke University. A joint PhD program with Duke will distinguish the PhD degree from the regional PhD degrees, thus enhancing the recruitment of many talented students in Asia, Europe and the USA.

e) The joint degree will further strengthen the bonds between the research and training programs at Duke and Duke-NUS. It is expected that more Duke faculty will actively participate in thesis advisory committees of IBM PhD students and consequently become more involved in the research projects at Duke-NUS. This can lead to new opportunities for research collaborations between Duke and Duke-NUS faculty and their students. As described in section 2, several programs are already in place to foster the collaboration between Duke and Duke-NUS, which are fully financed by Duke-NUS. One of the newer programs that the IBM program is currently developing is an exchange program for graduate students between Duke and Duke-NUS that will also be fully financed by Duke-NUS. Students from either program can spend time at the 'other' campus with the goal to engage in collaborative research. A joint degree program would further foster this program and may lower the barrier for Duke students to visit Duke-NUS and vice versa.

f) The IBM program provides new, uniquely attractive research opportunities for Duke. One of the five signature research programs is "Health Services and Systems Research (HSSR)", which focuses on organization, funding, and delivery of health services and employs systems perspectives to address critical health care issues. This involves the study of the structure, funding, and organization of existing health services and to provide research based, cost effective solutions to prevent or diminish health care burden. The scope of the program spans studying the economics of health behavior, evaluations of health promotion programs, research on policy implementation, and health care systems for an aging population. The HSSR group, lead by Prof David Matcher, who came to Duke-NUS from Duke University, is composed of leading researchers in their fields producing high quality studies on topics in Asia and globally. The research outcomes from the HSSR group have already had significant impact and are shaping policy-making in the health sector in Singapore. With many similar health care and health system problems in the US, this provides Duke faculty with unique opportunities to collaborate with Duke-NUS on these topics. This may consequently contribute substantively to the discussion in the US around



health care systems. This is a unique research program without a comparable research group or institute at Duke University, and one of a kind in Asia. Hence, this is an attractive opportunity for Duke faculty and students to engage in novel research questions pertaining to health economics, health care and health services.

Another unique program that does not have an equivalent at Duke is the signature research program in "Emerging Infectious Diseases (EID)." EID focuses on identifying novel treatments and vaccines for infectious diseases specific to South East Asia and of a concern to the US (e.g. Dengue, hepatitis B, influenza, SARs), with several research groups working on developing effective vaccines and therapies, which have resulted in recently published papers in the journal Science and initiation of clinical trials in Singapore. Several students from Duke have already spent a research semester in the EID research laboratories Duke-NUS, because similar resources and research opportunities are not present at Duke. Again, a joint degree would further increase the current synergy between Duke and Duke-NUS and foster additional exchanges.

g) In contrast to other global initiatives for graduate education by Duke, Duke-NUS faculty, staff and students, as well as the facilities and curricular resources are solely funded by local sources; in this case, all necessary funding is from the government of Singapore. Therefore, there is no direct financial liability to Duke University. The research and education building with top-flight laboratories and facilities opened in 2009. High quality research laboratories occupy five stories of the Duke-NUS building, with an additional annex completed in November 2014 that hosts a new functional MRI facility for clinical research.

h) Singapore has a stable, transparent, democratic government and open multi-cultural English-speaking society, and continues to be a strong ally of the US. Singapore continues to invest considerable sums of money into innovative biomedical education and research initiatives. By investing in Duke-NUS, Singapore has demonstrated an enormous commitment toward furthering the Duke name and reputation. A joint PhD degree with Duke and NUS would reciprocate that commitment by Duke University in line with the joint MD.

i) The National University of Singapore (NUS) is a high profile university, consistently recognized as one of the top three universities in Asia and top 50 in the world. NUS is already the partner of Duke for the medical degree at Duke-NUS. In addition, NUS's prestige has attracted the attention of other world-class universities, including Imperial College London and Australian National University, with which NUS has established joint graduate degree programs. A joint degree between Duke and Duke-NUS is a natural complement to the existing joint medical degree and a reflection of the close, successful relationship between Duke and Duke-NUS.

## **2. Relationship to existing programs at Duke**

### **2.1. Collaboration on IBM PhD curriculum review and teaching activities**

The IBM PhD is now in its fifth year, and 11 students, including two MD/PhD students, have so far graduated from the program. Details on student characteristics and program structure are listed under section 4 below.

With the awarding of a joint degree, Duke and NUS will both have a supervisory role in evaluating the curriculum and administration of the IBM PhD program at regular intervals (see oversight committee, page 28). This will provide an opportunity to remain aligned with the rigor of the Duke and NUS PhD programs and to gain advice on improvements. Similarly, it will provide opportunities to identify further collaboration on

the IBM program between Duke and Duke-NUS. With Professor Soman Abraham as the faculty liaison, with faculty appointments and active research groups at both Duke and Duke-NUS, this dialogue will be further and continually enhanced.

An important point from the Duke perspective is that SACS accreditors must be satisfied that Duke has a sufficient role in the program to merit degree sponsorship. In addition to the direct oversight by Duke faculty as discussed above, approximately a third of the course curriculum will be provided by Duke faculty (consistent with SACS expectations). For example, we are currently integrating recorded lectures given at Duke by Duke faculty in the medical school first year course sequence into the first semester Duke-NUS foundational course 'Molecules to Medicines'. Students will view the lectures in advance and then discuss them in class, in the context of primary research papers, with other students and Duke-NUS faculty. Following completion of this "flipped" course, our students take courses specific to the Signature Research Program (SRP) in which they work. The course directors in the IBM curriculum are primarily Duke-NUS faculty and many have joint appointments at Duke University (Table 4).

Duke-NUS is offering several classes within its SRPs that are registered as NUS graduate courses and thus available for NUS students. To this end several PhD students from NUS have already successfully completed some of our modules. Similarly, our students have the opportunity to choose from existing selected NUS graduate courses. In addition, several NUS courses are also co-taught by NUS and Duke-NUS faculty.

## 2.2. Collaboration on Research Activities

The establishment of Duke-NUS has provided new and exciting opportunities for research in Durham and in Singapore to advance biomedical science on a global scale. Under the new leadership of Dean Tom Coffman, an accomplished leader, physician and researcher from Duke University, this trajectory will certainly continue.

### a) High caliber research faculty at Duke-NUS.

Nearly one third of our faculty hold joint appointments with Duke (Table 4). This includes faculty who had an appointment at Duke prior to joining Duke-NUS and those that established an appointment at Duke after joining Duke-NUS, further extending close ties and expanding research and educational collaborations with Duke.

**Table 4: Faculty with Duke and Duke-NUS appointments (SRPs).**

<b>Signature Research Programs (SRP)</b>	
<b>CANCER &amp; STEM CELL BIOLOGY (CSCB)</b>	
Patrick J. CASEY	Sharon ENDOW
David EPSTEIN	Sin Tiong ONG
Steve ROZEN	Patrick TAN
David VIRSHUP	
<b>CARDIOVASCULAR AND METABOLIC DISORDERS (CVMD)</b>	<b>EMERGING INFECTIOUS DISEASE (EID)</b>
Thomas COFFMAN	Soman ABRAHAM
Paul Michael YEN	Gavin SMITH
<b>HEALTH SERVICES &amp; SYSTEMS</b>	<b>NEUROSCIENCE AND BEHAVIORAL</b>

RESEARCH (HSSR)	DISORDERS (NBD)
Eric A FINKELSTEIN	Michael HAUSER
David MATCHAR	Tih-Shih LEE
Truls OSTBYE	Antonius M.J. VAN DONGEN

**b) Research Collaboration between Duke and Duke-NUS**

Many researchers from Duke have taken the opportunity to collaborate with Duke-NUS scientists through the Duke/Duke-NUS Research Collaboration Grant, funded solely by Duke-NUS. The long-term goal of this program is the development of research teams between Duke and Duke-NUS that advance basic, translational and clinical research. Thus far a total of 17 research projects have been funded through this initiative (table 5). These collaborations allow students to work in the partner campus and to receive additional valuable training. For example, Angeline Tay, while a student in the IBM program with Professor Shenolikar, was involved in a collaborative project and had the opportunity to join the laboratory of Professor Nicchitta at Duke for three months. Not only did she gain significant training experience, but also became a co-author on a recent publication (Reid DW, Chen Q, Tay AS, Shenolikar S, Nicchitta CV. The unfolded protein response triggers selective mRNA release from the endoplasmic reticulum. *Cell*. 2014; 158(6): 1362-74.). Moreover, David Reid, the first-author on this joint work, is currently doing a post-doctoral fellowship at Duke-NUS. This serves as a good example of the research and educational exchanges that exist between Duke-NUS and Duke. We envision these exchanges to increase and also for Duke students to conduct some of their research at Duke-NUS. A joint degree will clearly help to foster this and lower perceived barriers for this.

**Table 5: Research collaborations funded Duke/Duke-NUS Research Collaboration Grants by the Duke/Duke-NUS Research Collaboration Grant**

	<b>Duke-NUS</b>	<b>Duke University</b>	<b>Project Title</b>
1	Lim Kah Leong	Tso-Pang Yao	The role of Parkin-HDAC6 complex in mitochondria quality control and Parkinson's disease
2	Mariano Garcia-Blanco	Timothy Haystead	Validation of host purine utilizing enzymes induced by Dengue and Yellow fever virus infection as novel targets for Anti-Flavivirus drug development
3	Michael Chee	Scott Huettel	Sleep-Deprivation Modulation of the Neural Responses to Reward and Risk
4	Mei Wang	Christopher Counter	Evaluation of the Therapeutic Potential of Novel eNOS Inhibitors Alone or in Combination with Other Agents for the Treatment of Oncogenic Ras-driven Cancers
5	Shirish Shenolikar	Christopher Nicchitta	Translational Control and Stress-induced Cell Death
6	Duane Gubler	Soman Abraham	Novel Treatment for Dengue Infections
7	Bhavani Sriram	Priya Kishnani	Collaborative Project between Duke Medical Genetics and Duke-NUS/KK Hospital to Develop and Expand the Clinical Trial Research Capacity in Neurodevelopmental Disorders and Rare Diseases
8	Leung Ying Ying	Virginia Kraus	A Randomized Controlled Trial of Colchicine for Symptom and Inflammation Modification in Knee Osteoarthritis
9	Lee Sang Hyun	Jen-Tsan Ashley Chi	Mitotic Catastrophe and Chromothripsis Caused by Metabolic Dysregulation
10	Babita Madan	Steven Crowley	The Role of Porcupine-Mediated Wnt Acylation in the Pathogenesis of Kidney Fibrosis
11	Ashley St. John	Gunn, Michael Dee	A Rapid Test for Dengue Clinical Severity
12	Wang Linfa	Christopher Woods	Detecting Interspecies Pathogen Transmission at Lola Ya Bonobo Sanctuary, Democratic Republic of Congo
13	William Hwang	Mitchell Horwitz	Addressing the Limitations of HSCT Using Umbilical Cord Blood Grafts
14	Stuart Cook	Douglas Marchuk	Identification of Modifier Genes for Dilated and Hypertrophic Cardiomyopathy
15	Subhash Vasudevan	Christopher Nicchitta	High Resolution Genomic Imaging of Host Cell and Viral Transcriptome Expression in Dengue Infection
16	Subhash Vasudevan	Timothy Haystead	Preclinical Development of Novel HSP90 Inhibitors for the Prevention and treatment of Chikungunya Virus Infections

**c) Exchange program for graduate students and postdoctoral fellows between Duke University and Duke-NUS.**

The goal of this exchange program, which will start in 2016, is to foster and initiate collaborative research between the two campuses and to provide additional training opportunities for students at Duke or Duke-NUS. Students from PhD programs at Duke or Duke-NUS can apply, which is fully funded by Duke-NUS. Students will identify a specific laboratory at the partner campus and provide a proposal detailing how this

exchange would enhance their research project and training. A joint degree will again benefit this program and also lower the barrier for students from Duke or Duke-NUS to apply. All costs are borne by Duke-NUS.

#### **d) Joint Research Retreats between Duke-NUS Signature Research Programs and academic and clinical departments at Duke.**

Joint retreats between Duke-NUS and Duke provide a platform to discuss shared research interests and generate ideas for collaborative projects, and is an excellent opportunity to further foster the Duke culture among Duke-NUS faculty. Signature Research Programs hold joint retreats solely funded by Duke-NUS with Departments at Duke University to further strengthen and deepen the relationship between research programs. A short summary of past joint retreats for four of our SRPs is provided below. It is important to note that symposia for EID and CVMD were hosted in Singapore, providing our PhD students with the opportunities to participate, learn and interact with faculty from Duke. Duke-NUS funds this program even when the symposium is held at Duke. Of note, several research collaborations have already provided some of our PhD students with the opportunity to work for three-month attachments in laboratories at Duke University.

#### **Cancer Stem Cell Biology (CSCB) (appendices 1 & 2)**

The joint Duke/Duke-NUS/NCCS symposium 'The Singapore Connection' was held at Duke University September 22<sup>nd</sup>, 2014. At this one-day symposium, researchers from the SRP in Cancer Stem Cell and Biology (CSCB), the National Cancer Centre Singapore (NCCS) and Duke gave research talks and poster presentations on their latest research in the field. This symposium, which was preceded by a joint retreat of the CSCB Program faculty and the Pharmacology and Cancer Biology Department at Duke on September 19-21, provided an excellent venue to initiate research collaborations and networking between Duke and Duke-NUS faculty, students and postdoctoral fellows.

#### **Emerging Infectious Disease – EID (appendices 3 & 4)**

The Duke/Duke-NUS Symposium entitled 'Insights and Solutions for Emerging Infectious Diseases' was held in 2013 over two days at Duke. Presentations by Duke and Duke-NUS focused on topics important to infectious disease. Duke-NUS graduate students also had an opportunity to present their research during a poster session. The subsequent joint symposium was hosted in Singapore in March 2015.

#### **Cardiovascular Metabolic Disorder –CVMD (appendix 5)**

The Duke-NUS and Duke Symposium in Cardiovascular and Metabolic Disorders was held on January 19th and 20th, 2015 in Singapore. The objective of this symposium was to bring together leading researchers in the area of CVMD from Duke University, Duke-NUS and major researchers around Singapore for the specific goal of developing partnerships and collaborations in this field. The symposium involved approximately 16 speakers and 50 poster presentations. The speakers were from Duke University, Duke-NUS, the National Heart Center Singapore, A\*STAR and Singapore General Hospital. Students from the Duke-NUS IBM PhD program gave poster presentations and engaged in discussions with faculty from Singapore and Duke.

#### **Health Services and Systems Research – HSSR (appendix 6)**

The program for Health Services and Systems Research held a symposium on non-communicable diseases in March 2015 (appendix 9). Notably, this 'bridging' Symposium brought together experts from all three schools, namely Duke-NUS, Duke-Durham and Duke-Kunshan to share state-of-the-art evidence and to identify innovative ways to move both research and practice forward.

**e) Travel grant program for Duke faculty.**

The purpose of this program is to promote the development of collaborative research projects between the two institutions. This is a competitive grant application, in which Duke faculty are asked to describe how their research would benefit from a visit to Duke-NUS. The travel grant, solely funded by Duke-NUS provides air travel, accommodations and a daily stipend to Duke faculty. Approximately 8 grants are awarded each year.

**f) Research seminars and visiting research scheme**

Additional opportunities that contribute to the outstanding research environment at Duke-NUS and provide a conduit for research exchanges are the Signature Seminar Series, in which faculty from Duke and other renowned institutions present their work. Once again, this seminar series is funded by Duke-NUS.

Early on, after the establishment of the SRPs, Senior Vice Dean for Research, Professor Pat Casey commenced a weekly Signature Seminar Series providing a forum for leading researchers in their respective fields to present their work. Speakers participating in the seminar series for the last two years are listed in Appendices 7 & 8. Beyond the Signature Seminar Series individual SRPs also invite renowned faculty to Duke-NUS for talks and to engage in collaborations (Appendix 9). Faculty, research fellows and graduate students attend these seminars regularly to learn and discuss new developments in the different research areas. With many speakers coming from Duke University the seminars also provide an excellent platform for identifying research collaborations between the two institutions. For IBM graduate students these seminars are an important forum to gain knowledge about a specific research topic, and an opportunity to interact with renowned faculty. As part of the faculty visit to Duke-NUS, graduate students meet with the invited speaker gaining important insights from discussing topics that range from research methods to career advice.

Taken together, all of the activities described above are a reflection of the vibrant research environment at Duke-NUS, including frequent and consistent exchanges between Duke and Duke-NUS faculty and students. These allow for ample opportunities for the development of productive collaborations between faculty, and learning and research opportunities for Duke-NUS IBM PhD students. Duke-NUS provides a direct conduit for Duke University students and professors to access collaborations in the thriving biomedical research enterprise in Singapore and Asia. Conversely, it further strengthens NUS's presence at Duke and in the United States.

**3. Statement of resources needed for the program.**

Duke-NUS Graduate Medical School was established in 2005 and is currently in its second (2012-2017) phase. The operations of the school, including full faculty salaries, are funded by the Singapore government, and additionally the School has grown an endowment that now exceeds US\$350 million. Duke-NUS is currently finalizing with the Singapore Government for the third phase (2017 – 2022) of the School; while the final figures will not be released until October it is already clear that the funding for the IBM Program will be maintained.

The Duke-NUS research and education building, a vertical campus stretching over 11 floors comprising 280,000 square feet, opened in 2009 and houses state of the art research and teaching facilities. The first cohort of medical students started in 2007 and the PhD program in 'Integrated Biology and Medicine' (IBM) was established in 2010. PhD students receive a monthly stipend for the duration of the program and tuition fees are covered. Health insurance is provided as well.

Research at Duke-NUS is funded by the government and faculty obtain extramural funding through competitive research grants from the National Medical Research Council (NMRC) and National Research Foundation (NRF) of Singapore. Thus far, the Duke-NUS research faculty has attracted more than S\$290 million in competitive research funding. Research resources including laboratories and core research facilities are located within the Duke-NUS building. In addition, strong links are established to other research institutes in Singapore, including NUS and A\*STAR, providing access to research facilities when needed. In summary, there has never been a financial commitment required from Duke, and **no financial resources are needed from Duke** for the Duke-NUS IBM PhD program.

### **3a. Review of budget and resources available (personnel, financial, space, library, etc.).**

Duke-NUS has continually secured a sufficient budget to allow for the matriculation of 15 IBM PhD students each year, and their full support (including tuition, stipend, required fees) for five years for each admitted student. Funding sources are primarily from the Ministry of Education (MOE), and the Ministry of Health (MOH), with a small component from philanthropic sources. We have not yet had a student taking longer than 5 years to complete, but if the case arises and the student is in good standing we will ensure they can complete the degree. Research and seating space for the students are provided in the mentors' laboratory, and the Office of Graduate Studies (OGS) provides shared workstation space if needed. The OGS is led by Associate Dean Silke Vogel, who is assisted by a staff of three. Students have full access to the physical library and e-journals of the National University of Singapore (NUS). The Director of Graduate Studies is Associate Prof. David L. Silver of the CVMD Program.

### **3b. Statement of additional resources needed.**

There are no additional financial resources needed for the IBM PhD program, and no resources are required from Duke.

### **3c. Potential or actual outside funding.**

As noted in (a), full funding for the program is provided by Duke-NUS via funding streams it receives from respective Singapore government agencies and various philanthropic sources.

### **3d. Five-year student, faculty and resources projections**

The fees, tuition and stipend amounts required for each student is roughly S\$50K/yr., or S\$250K (~US\$192K) for the 5-year course. Hence, direct student costs are roughly US\$2.9M per year. Faculty salaries in Singapore are covered in full by the Ministry of Education, i.e. faculty are on "hard money" salaries. The overall costs associated with maintenance of the Office of Graduate Studies, and its associated functions, is roughly US\$200,000/year and is a line item in the overall budget of the School.

As noted above, Duke-NUS is currently in phase II and has established a phase III (2017-2022) budget that includes resources for the PhD program, faculty salaries and core research support.

## **4. Students (sources, characteristics, opportunities available to students).**

In 2010, the first students matriculated into the IBM PhD program. Currently, 48 students are enrolled in the IBM PhD program, and 11 students had graduated by August 2015. (See appendix 10 – public seminar announcements).

### **Recruitment, admissions and student characteristics**

#### **Qualifications:**

Applicant qualifications and requirements are similar to those required for matriculation into Duke University Graduate School. Applicants need to have completed a Bachelor's or a Masters' degree in Science, undertaken the Graduate Record Exam (GRE), ideally posting a score above 310 (analytical & quantitative) and have prior research experience, with an evidently strong commitment to research training. Applications from candidates scoring below a GRE score of 310 are reviewed and considered on a case-by-case basis. Medical students applying to the PhD program need to provide their MCAT scores rather than GRE results. Applicants from non-English speaking countries are required to provide test scores for the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). Minimum required scores are 100 for an Internet-based TOEFL or 7.0 for the IELTS. Students that studied full-time at a college or university where the sole language of instruction is English are exempt from taking the TOEFL. Overall these qualifications are similar to those required by the Duke Graduate School.

**Recruitment and Admissions**

In Singapore, recruitment efforts focus on attracting the top students in undergraduate departments and programs of the two major universities, National University of Singapore (NUS) and Nanyang Technical University (NTU). Together with recruitment efforts by the Duke-NUS MD program, the IBM program hosts monthly open houses and webinars. In addition, our faculty give regular recruitment talks for the MD and the PhD programs in the United Kingdom, China, and the USA.

**Table 6:** Applicants and enrolled students to the IBM PhD program at Duke-NUS.

Intake Year	2010/11	2011/12	2012/13	2013/14	2014/15
Applicants	57	46	65	66	125
Interviewed	32	26	42	43	45
Offered	13	17	18	20	20
Enrolled	11	9	13	14	13
GRE (mean; range)	1398 (1310-1455)	1380 (1320-1440)	318 (312-325)	318 (309-328)	322 (312-333)
GPA (mean; range)	3.6 (3.1-3.8)	3.8 (3.2-4.0)	3.6 (3.2-3.9)	3.6 (3.0-3.9)	3.6 (3.1-4.0)
MD/PhD (total)	2	8	11	15	18
Full enrollment	11	20	33	45	49
Doctoral Degree Awarded	-	-	-	-	10

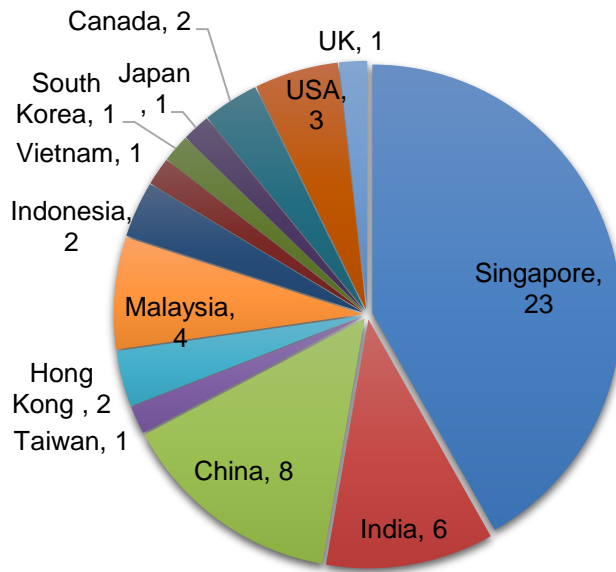
On average, 40 students are selected from the applicant pool to attend Applicant Day where prospective students are interviewed by three Duke-NUS research faculty. A least one of the interviewers is a member of the Admissions Committee. Students unable to attend applicant day are interviewed via Skype. The admissions committee, composed of two faculty from each SRP, reviews and discusses the dossier of each interviewed student and ranks the candidates. Of the students given offers to attend Duke-NUS, approximately 65 % accept the offer to join the IBM PhD program (table 6). More details on students' statistics are shown in appendix 11.

**Student Characteristics and Sources.**

Since our inaugural intake of 11 students in 2010, the program has grown to 55 students and three students recently defended their theses (TABLE 6). Out of the 55 students, 42% are Singapore Citizens, while the remaining 48% are international students from 12 different countries (figure 1).

**Figure 1: Citizenship of students IBM PhD students.**





More than half (57%) of the students are women and the mean age of the student body is 25 years. As mentioned, medical students wishing to pursue a PhD join the program after their first two-years of medical school in lieu of their third year research year. Currently, of the 49 students, 18 are MD/PhD students.

The mean GRE scores for our students are comparable to those for students in the basic sciences at Duke University (table 3). About 20% of our students hold a Masters Degree and the majority of students have studied abroad prior to joining Duke-NUS. University and colleges that our students have attended are listed in table 7.

Table 7: Universities attended by students prior to joining IBM PhD program

<p><b>USA</b>            Bucknell University            Carnegie Mellon University            Cornell University            Duke University            Gordon College            Johns Hopkins University            New York University            Northwestern University            St Lawrence University            University of Chicago            University of California, Irvine            University of Pennsylvania            University of the South, Sewanee            University of Wisconsin-Madison</p>	<p><b>Singapore</b>            National University of Singapore (NUS)            Nanyang Technological University (NTU)</p>
<p><b>Canada</b>            University of Toronto            University of British Columbia</p>	<p><b>Australia</b>            Curtin University            Monash University            Murdoch University            University of Melbourne            University of Western Australia</p>
<p><b>United Kingdom</b>            Imperial College            University College, London            University of Durham            University of Edinburgh            University of Manchester            University of Oxford</p>	<p><b>India</b>            Anna University</p> <p><b>China/Taiwan</b>            Peking University            Shanghai Jiao Tong University            National Taiwan University</p>

### **5. The Graduate Program Organization:**

The Program of Graduate Studies is part of the Office of Education and is led by the Associate Dean of Graduate Studies who has the administrative and academic oversight of the IBM PhD program. The Director of Graduate Studies (DGS), a tenured faculty from one of the SRPs, in his/her capacity chairs the Graduate Program Executive Committee (GPEX), advises students on research related matters, provides guidance for the PhD qualifying exam and liaises with faculty in matters related to the program. Associate Professor David Silver is the current DGS for the program.

### **Below are committees specific to the IBM PhD program.**

#### Graduate Program Executive Committee (GPEX)

The executive committee is comprised of five faculty members, one from each of the five Duke-NUS Signature Research Programs (SRP), and is chaired by the DGS. Additionally, Professor Soman Abraham, Director of Graduate Studies in Pathology at Duke, will be joining the Committee. The Duke-NUS Associate Dean, Office of Graduate Studies, attends the meeting and presents policies and guidelines for discussion to the committee.

**Table 8: Chair and members of the Graduate Program Executive Committee**

Role	Name	Title	SRP
Chair & DGS	David Silver	Associate Professor	Cardiovascular & Metabolic Disorders
Member	Marcel Bilger	Assistant Professor	Human Services & Systems Research
Member	Hongyan Wang	Associate Professor	Neuroscience & Behavioral Disorders
Member	Koji Itahana	Assistant Professor	Cancer & Stem Cell Biology
Member	Gavin Smith	Associate Professor	Emerging Infectious Diseases
Ex officio	Silke Vogel	Associate Dean	Office of Graduate Studies
Duke Member Faculty Liaison	Soman Abraham	Professor & DGS	Departments of Pathology, Molecular Genetics & Microbiology

The committee is charged with setting the strategic goals of the PhD program, approving guidelines and policies relevant to the program (e.g. graduation policy; PhD qualification exam) and reviews the curriculum to identify additional needs such as new SRP-specific classes. Furthermore, the committee is charged with approving faculty mentors within the IBM program.

#### Admissions Committee

The Admissions Committee is comprised of 10 faculty members, two from each of the five Duke-NUS Signature Research Programs (SRP).

**Table 9: Chair and members of the PhD Admissions Committee**

Signature Research Program	Member	Member
Cancer & Stem Cell Biology	Koji Itahana	Mei Wang-Casey
Cardiovascular & Metabolic Disorders	David Silver	Jean Paul Kovalik
Emerging Infectious Diseases	Eng Eong Ooi (CHAIR)	Sheemei Lok
Human Services & Systems Research	Marcel Bilger	Angelique Chan
Neuroscience & Behavioral Disorders	Shawn Je	Helen Zhou

A senior faculty member chairs the committee for a term of three years. The Admissions Committee is charged with identifying the most promising candidates for the IBM program. Each member of the committee interviews several candidates during the annual Applicant Day or, if needed, via Skype. The Admissions Committee then meets to review each application, results of the interviews, and to discuss the candidates. Subsequently, the applicants are ranked and the committee makes recommendations for admissions to the Senior Vice Dean of Research, Professor Pat Casey.

#### Academic Affairs Committee

The Academic Affairs Committee is charged with tracking the academic progress of all IBM graduate students and mitigating any problems and conflicts that arise while the student is in the program. The aims of this committee are to ensure that students meet their milestones such as passing coursework, completion of the PQE, and engage in regular thesis advisory committee meetings. The committee meets bi-yearly or if special cases emerge, ad hoc. The Associate Dean of Graduate Studies chairs the committee, which is composed of a faculty representative from each SRP.

**Table 10: Academic Affairs Committee**

Role	Name	Title	Signature Research Program
Chair	Silke Vogel	Associate Professor	Associate Dean, Office of Graduate Studies
DGS	David Silver	Associate Professor	Cardiovascular & Metabolic Disorders
Member	Marcel Bilger	Assistant Professor	Human Services & Systems Research
Member	Sheemei Lok	Associate Professor	Emerging Infectious Diseases
Member	Shang Li	Assistant Professor	Cancer & Stem Cell Biology
Member	Sun Lei	Assistant Professor	Cardiovascular & Metabolic Disorders
Member	Hongyan Wang	Associate Professor	Neuroscience & Behavioral Disorders

Opportunities available for graduates

We recently launched a Career Development Program (CDeP) as an onsite career counseling resource for Duke-NUS PhD students. This program aims to provide guidance and resources on career and professional development, for example one-on-one sessions, development plans and workshops. In addition it will complement efforts to train scientists in technology development and application to support R&D manpower needs in Singapore.

Singapore has a vibrant research environment including top universities and research institutions along side a strong pharmaceutical industry presence. Our graduate students have a multitude of opportunities to complete postdoctoral fellowships in one of the many research groups located at A\*STAR, NUS, NUHS, NTU, Temasek Life Science Institute, institutes of Singapore General Hospital, and Duke-NUS. An increased presence of pharmaceutical Research & Development divisions in Singapore (e.g. Proctor&Gamble, Johnson&Johnson, Abbott Nutrition, GSK, Merck, Boehringer Mannheim, etc.) provides additional career opportunities for our graduates. Alternatively, students can join one of the government agencies, e.g. Ministry of Education, Health Science Authority or Ministry of Health.

Five of our recent graduates have joined research laboratories as postdoctoral research fellows at A\*STAR, once graduate joined a biomedical company in Germany while another student is working at the research laboratories MSD Merck in Singapore. One of our students, who completed her thesis work within the HSSR SRP, is joining Duke Kunshan University as a postdoctoral research fellow. Among the MD/PhD students, one student graduated with his MD/PhD degree and will start his residency this August. The second MD/PhD student is returning to the medical school to complete her fourth year. She is on track to graduate with an MD/PhD degree in May 2016.

The impact of a joint degree may be felt strongly in opportunities for our graduates. A joint degree set the students more clearly apart from other NUS PhD graduates. A joint degree is also likely to attract more high-achieving students, to strengthen the ties between the research programs at Duke and Duke-NUS and to foster more collaborations. As a result, talented students may be very much attracted to join Duke University for post-doctoral positions.

**5. Degree requirements and Curriculum**

The degree requirements for the program are comparable to those set forth for the Duke Graduate School and include successful completion of coursework, a pass on the PhD qualifying exam (PQE), and the completion of a dissertation with a successful dissertation defense (Figure 2). In addition, students are required to fulfill the manuscript

requirement of at least one peer-reviewed, first-author research manuscript (published or in revision) .

**Figure 2: Curriculum Overview**

	Semester 1	Semester 2
<b>Year 1</b>	Lab rotation 1   Lab rotation 2   Lab rotation 3	Start of thesis research
	IBM class: Molecules to Medicines	SRP specific courses
		Student Research Seminars
<b>Year 2</b>	Thesis research	Thesis research
	SRP specific courses	PhD Qualifying Exam (PQE)
	Student Research Seminars	Student Research Seminars
<b>Years 3 to 5</b>	Thesis research	Thesis research
	Student Research Seminars	Student Research Seminars
		Dissertation & Defense

### Curriculum

The PhD curriculum utilizes a teaching approach that combines lectures with team-based teaching strategies that aid in transitioning students to a mode of learning conducive for graduate education and lifelong learning in biomedical sciences. The lectures provide in depth content while the team-based learning approach program reinforce critical thinking, scientific discussions, and rigorous analysis of scientific publications.

In partial fulfillment of the PhD degree, IBM students are required to obtain a minimum of 60 modular credits (MC). Modular credits are a unit of effort that reflects the workload hours expected for a course per week. Students typically take four credit courses, which requires approximately 10 hours of work a week. The 60 modular credits are accumulated through course work, lab rotations and thesis research. In addition, only courses taught at a graduate school level, indicated as level 5000 or above, count toward the credit requirements. Coursework needs to be completed by the end of Year 2.

As noted earlier, approximately a third of the course credits will result from courses taught by Duke faculty.

### Foundation Course – Molecules to Medicines

The IBM PhD program requires that all students take the core foundation course ‘Molecules to Medicines’ in the first semester of the first year (Syllabus see appendix 12). The course is organized into six blocks grouping relevant topics into each block progressing from basic science content to translational areas of human disease and drug discovery (table 11).

**Table 11: Topic domains for ‘Molecules to Medicines**

TOPICS
Block 1: Research methods and model organisms
Block 2: Macromolecules and regulatory processes
Block 3: Cells and neurons
Block 4: Human disease
Block 5: Medicine - drug discovery and development
Block 6: Health services and systems research

The goals for the course are to provide the student with a foundation in basic sciences such as biochemistry, cellular and molecular biology, and broad knowledge of applied research methods and essential concepts relevant to translational research. Emphasis is placed on learning to critically evaluate the research literature, and extend the course content through interactive discussions during class time.

For each topic within 'Molecules to Medicines', the faculty spends two consecutive days (each day three hours of class time) with the students. The students prepare extensively before the first class, reviewing online lectures and reading materials provided by the faculty. A majority of the recorded lectures are presented by Duke faculty, which provides an important content base for the course. On the first day for the individual topics class time is used for review of the essential content relevant to the topic. This includes assessment tests to ensure that the students reviewed and studied the material. This is followed by a lecture from the local faculty member responsible for the topic. A group discussions on the materials with the faculty member will then include answering questions on the topic and around the assessment test. On the second day emphasis is placed on encouraging the students to extend their thinking and apply content learned the first day. This can entail, but is not limited to, guided discussions of a relevant research papers, working in groups on identifying strengths and weaknesses of a research study or identifying alternative research approaches to a given research problem.

### Responsible Conduct of Research (RCR)

Students are required to undertake mandatory training in "Responsible Conduct of Research" which aims to deliver a clear message regarding academic integrity and research ethics (Table 12). Throughout the first semester, students continue their RCR training participating in six two-hour RCR sessions, each centered on a specific topic related to research conduct.

The sessions are led by faculty from Duke-NUS and NUS. The content was developed based on RCR training at Duke University. In addition, during orientation week, students participate in introductory RCR discussions and a three-hour safety-training lesson that includes discussions on safety training requirements, reporting accidents, biological agents and hazardous materials.

The overall amount of RCR training is comparable to the 18 hrs of training required of Duke biomedical PhD program students.

**Table 12: Responsible Conduct of Research**

Faculty	Topic
<b>Viji Vijayan</b> <i>Director, Research Operations and Director, Department of Safety, Health and Environment</i>	Laboratory safety training, biological agents& hazardous material
<b>Shirish Shenolikar, PhD</b> <i>Interim Director &amp; Professor in Neuroscience &amp; Behavioral Disorders Program; Cardiovascular &amp; Metabolic Disorders Program</i>	Overview of Scientific Conduct
<b>Antonius Van Dongen, PhD</b> <i>Associate Professor, Neuroscience &amp; Behavioral Disorders Program</i>	Laws, Ethics, and Professionalism; Handling Misconduct Allegations
<b>Bryan Ogden</b> <i>Director &amp; Chief Veterinary Officer SingHealth Experimental Medicine Centre</i>	Ethical Research in Animals
<b>Patrick Casey, PhD</b> <i>Senior Vice Dean of Research Professor, Cancer &amp; Stem Cell Biology Program</i>	Ethics and Policy

<b>Rahul Gopalkrishnan, PhD</b> <i>Senior Associate Director National University of Singapore</i>	Maximizing Your Research Output by Effective IP Strategies” talk (Intellectual Property)
<b>Stella Quah, PhD, MSc</b> <i>Adjunct Professor Health Services &amp; Systems Research Program</i>	Plagiarism, Responsible Conduct of Research, and Allocation of Credit/Authorship

**Courses for each SRP**

From the second semester forward students take coursework specific to their Signature Research Program in which their thesis research lab resides. These SRP-specific courses provide in-depth knowledge of a particular SRP-related research area. Course directors of the many of these disease specific courses are faculty that also have an appointment at Duke University.

Typically, the students take two 4-credit classes in a relevant disease area. Students can obtain permission from their mentors to participate in coursework offered by other SRPs. This may be especially helpful when a project overlaps with research areas outside the student’s SRP.

HSSR has unique requirements for their students with additional coursework totaling seven four-credit courses. These additional credits are essential to provide additional content specific to HSSR. Courses for each SRP are described under section 6 in this proposal.

**PhD Qualifying Exam (PQE)**

All students are required to pass the PQE at the end of the second year before continuing with their thesis research. The purpose of the PQE is to assess the breadth and depth of the students’ knowledge and thinking skills and to determine if there are any major limitations that would hinder the student from conducting thesis research. Successful completion of the PQE marks a student’s transition to “PhD candidate” and further development toward independence.

The PQE committee consists currently of four faculty members that are approved mentors for the IBM program. As required by the ECGF committee and in any case a good suggestion, moving forward, one of the four members will be a Duke professor who is a full member of the Graduate Faculty at Duke University in a related department (see section 8).

Like the preliminary examination in many Duke departments, the PQE involves two components, a written grant proposal and an oral defense. The grant proposal is expected to describe the thesis project in which a central hypothesis or goal is tested or undertaken, with clear descriptions of two to three specific aims. The written proposal must be the independent work of the student and describe background and significance, approach and expected outcomes and alternative plans. Students can obtain assistance from their mentors on the general scope and ideas of the proposal before the initiation of writing. The “budding” thesis project as written up by the student for the written component of the exam provides a scaffold for questioning during the oral exam. At the beginning of the oral defense component of the PQE, the student makes an uninterrupted 10-15 minute oral presentation describing the proposal. This is followed by the examination itself, which involves questioning by the examiners. The student will be asked questions in order for the examiners to determine their general and specific knowledge obtained from the coursework and relevant literature, and of experimental strategies and the ability to think on their feet and across the “pitfalls” (controls, alternative approaches, etc.). The exam is expected to run approximately 90 minutes. If necessary, the Chair of the PQE may stop the exam for a brief discussion, or to allow the student to take a short break. A student successfully “passes” the PQE by being able to demonstrate a broad understanding of the basic biology underlying the thesis question(s), and would have demonstrated critical thinking skills regarding theory, approach and interpretation of data.



## **Research Requirements**

### Laboratory Rotations

Students are required to complete three, six-week research rotations during the first semester. The IBM program encourages students to explore research topics in multiple research areas before committing to a thesis laboratory. To facilitate this goal, students are required to complete a minimum of two rotations in two separate SRPs. At the completion of each rotation the student is required to write up a short summary, which is then discussed with the PI. This exercise of writing up a summary of their rotation work allows the student and PI to evaluate the work completed during the rotation and determines if the lab might be a good match for the student. After completion of three rotations, the student declares his/her research thesis setting with one of the approved thesis mentors. Students will then begin their thesis research in the second semester of the first year. Every six months the thesis mentor is asked to evaluate the student and indicate whether he/she is in satisfactory standing.

### Thesis Advisory Committee (TAC)

Upon the successful completion of the PQE, the PhD candidate will assemble a Thesis Advisory Committee (TAC). The purpose of the TAC is to provide scientific guidance to the development of the student's thesis research. The TAC meets with the student every six months to discuss the student's research progress, identify pitfalls and potential solutions, discuss data interpretation, and determine future milestones. The TAC committee is composed of the student's thesis mentor plus three to four faculty, of which three are approved mentors in the IBM program (not including the mentor). A fourth and in some cases a fifth member can be professors from outside the IBM program that provide unique expertise beneficial to the student's thesis research. Each TAC meeting is documented by having faculty complete a recommendation form on progress and goals of the project. The chair will summarize these comments on a 'TAC summary form', which will be handed in to the Office of Graduate Studies and used as a starting guide for the next TAC meeting. Importantly, the TAC is charged with determining whether the student is ready to write and defend her/his thesis.

### Dissertation, Dissertation Defense and Graduation

The granting of the Ph.D. degree is targeted for the end of Year 4 or during Year 5 with the submission of the thesis, and a dissertation defense.

The dissertation is expected to be the all-encompassing document describing the results of significant and original research by the graduate student. In general, the student's thesis research answers a research question or a group of research questions and has generated a body of novel data that has advanced his/her field. Every candidate for the PhD degree must submit a written dissertation and pass an oral examination of their dissertation (the Dissertation Defense) by a Dissertation Defense Committee. The dissertation defense committee is composed of three approved IBM mentors, one outside non-Duke-NUS expert and will henceforth include a full time, full member faculty of Duke Graduate Faculty.

### Manuscript Requirement

Students are expected to publish at least one first-author, high quality, peer-reviewed scientific article describing a body of original scientific work prior to the dissertation defense. If this is not achieved, the Office of Graduate Studies requires that at least one peer-reviewed, first author manuscript is under revision at an internationally reputed journal before the student can defend his/her dissertation. The submitted manuscript must be appended to the thesis.

Once the student has fulfilled all requirements including course work, PQE, dissertation defense, submission of final written thesis, and the publication requirement, Duke-NUS informs NUS to issue a letter of conferment to the student.



## 6. Description of new courses to be offered in connection with the program and identification of teaching faculty.

The courses offered within the PhD program are listed in Table 13. Several courses are Duke-NUS module courses meaning they have been developed and implemented by Duke-NUS faculty. This is reflected in the course number starting with 'GMS'. The remaining courses were co-developed with faculty at NUS and A\*STAR. Details on each class including syllabus and teaching faculty are provided in Appendix 13. Of note many of course directors also have an appointment at Duke, ensuring for additional rigor and high quality content.

**Table 13: Course offered in IBM PhD program.**

<b>Course Module Requirements</b>	<b>Credits</b>
<b>Semester 1</b>	
Core Course: GMS6901 - Molecules to Medicine Responsible Conduct of Research	4
<b>Semester 2 onwards</b>	
Core Course: GMS6900 - Student Research Seminar (6 semesters)	3
<b>Cancer and Stem Cell Biology (CSCB)</b>	
CDN5101 Fundamentals of Cancer Biology Course	4
CDM5102 - Translational Cancer Biology	4
<b>Emerging Infectious Diseases (EID)</b>	
GMS 6904 - Principles of Infectious Diseases Course	4
GMS 6910 - Evolutionary Genetics	4
<b>Cardiovascular and Metabolic Disorders (CVMD)</b>	
GMS 6920 - Metabolic Basis of Disease	
GMS6921 - Cardiovascular Molecular Biology	4
<b>Neuroscience and Behavioral Disorders (NBD)</b>	
GSN6501 - Neuronal Signaling	4
GSN6505 - Brain Disorders and Repair	4
GSN6503 - Techniques in Neuroscience	4
GSN6881 - Human Cognitive Neuroscience: A hands on approach	4
<b>Health Services &amp; Systems Research (HSSR)</b>	
GMS6950 – Health Services and Systems Research	4
<i>Courses (decided by Student &amp; Mentor):</i>	
Additional modular credits of 6000 level (2 courses)	8
Additional modular credits of 5000 level or higher (4 courses)	16

## 7. Faculty who will participate in the program.

Currently, the IBM program has 56 approved thesis advisors, which have been approved by the Graduate Program Executive Committee (GPEX) (table 14). All approved mentors hold regular rank, tenure track appointments. In addition, many of the faculty also have appointments at various departments at Duke USA (table 4). The curriculum vitae of the faculty are shown in appendix 14.

**Table 14: Approved thesis mentors for the IBM program.**

<b>Cancer &amp; Stem Cell Biology</b>	<b>Cardiovascular &amp; Metabolic Disorder</b>
Prof. David Marc Virshup	Prof Thomas Coffman
Prof. Patrick Casey	Prof. Paul Michael Yen
Prof. Patrick Tan	Prof. Stuart Cook
Asst. Prof. Koji Itahana	A/Prof. David Lawrence Silver
A/Prof. Ong Sin Tiong	A/Prof Enrico Petretto
A/Prof. Lee Guat Lay, Caroline	Asst. Prof. Jean-Paul Kovalik
Asst. Prof. Mei Wang-Casey	Asst. Prof. Sugii Shigeki
Asst. Prof. Li Shang	Asst. Prof. Manvendra Singh
Prof. Kanaga Sabapathy	Asst. Prof. Sun Lei
Prof. Pervaiz, Shazib	Prof. Karl Tryggvason
A/Prof. Steven George Rozen	Prof. Derek Hausenloy
Asst. Prof. Lee Sang Hyun	<b>Neuroscience &amp; Behavioral Disorders</b>
Asst. Lisa Tucker-Kellog	Prof. Michael Chee
Prof. Teh Bin Tean	Prof. Tan Eng King
A/Prof. Jerry Chan Kok Yen	Asst. Prof. Marc Laurent Fivaz
<b>Emerging Infectious Diseases</b>	A/Prof. Antonius M J Van Dongen
Prof. Wang Linfa	Asst. Prof. Eyleen Goh
A/Prof. Eng Eong Ooi	Asst. Prof. Joshua J Gooley
Prof. Duane J Gubler	A/Prof. Lee Tih-Shih
A/Prof. Sheemei Lok	A/Prof. Lim Kah Leong
Prof. Subhash Vasudevan	A/Prof. Wang Hongyan
A/Prof. Gavin James Smith	Asst. Prof. Zhang Xiaodong
Asst. Prof. Manoj N Krishnan	Asst. Prof. Adam Claridge-Chang
Prof. Antonio Bertoletti	Asst. Prof. Hsieh Po-Jang
Asst. Prof. Ashley St. John	Asst. Prof. Shawn Je
<b>Health Services &amp; Systems Research</b>	Asst. Prof. Helen Juan Zhou
Prof. David Bruce Matchar	A/Prof. Jesuthasan Suresh Jeyaraj
Prof. Eric Andrew Finkelstein	
A/Prof. Chan Wei-Ming, Angelique	
Asst. Prof. Marcel Bilger	
Prof. Tazeen Hasan Jafar	
Prof. Truls Ostbye	

The quality of faculty mentorship of graduate students is supported through various approaches. With support of the Office of Education at Duke-NUS, we will be organizing a workshop in 2016 specifically tailored to our IBM faculty. The goal of this interactive workshop is for the faculty to recognize the significance of the mentor-mentee relationship and to enable them to integrate different approaches into their mentoring of students. Furthermore, the mentor-mentee relationship will also be fostered through the career development program, specifically through implementing individual development plans (IDP). These IDPs can be a useful tool to enhance conversations about current skills, potential barriers and career preparations between the mentor and student. In addition, we already have several informal faculty mentoring processes in place such as having experienced faculty chair the TAC and PQE committees.

## **8. Long term sustainability of Duke faculty involvement and capacity to conform to Duke Graduate School's education and training standards.**

The previous sections established that milestones in the IBM PhD program are aligned with those in graduate programs at NUS as well as those established for graduate programs at Duke University. Furthermore, incoming students for the IBM PhD program have GRE scores and undergraduate GPA metrics comparable to those joining PhD programs at Duke University (table 3).

A key element of our proposal is that the Duke-NUS IBM students will be required to meet the same standards as Duke PhD students, as defined by Duke Graduate School and the Executive Committee of the Graduate Faculty.

The following list shows the requirements that the Duke-NUS IBM students will meet in the same way as Duke students:

- Meet admissions thresholds: baccalaureate degree from accredited institution; GPA  $\geq 3.2$ ; GRE  $\geq 308$  (MCAT may be considered instead); TOEFL 90 (if from a primarily non-English speaking background or institution); review and selection by a faculty admissions committee of the program.
- Training in Responsible Conduct of Research, 18 credits or equivalent, including both Orientation and ongoing training sessions.
- Coursework and research experiences as mandated by the program's requirements.
- Preliminary examination for progression to degree candidacy complete by end of year 3, or earlier as defined by program.
- Milestone (prelim and dissertation) examination committees composed of four or more approved members of the Duke Graduate Faculty, with composition authorized by Director of Graduate Studies and Associate Dean for Academic Affairs, Duke Graduate School.
- Committees must vote pass or fail at the conclusion of a milestone exam, with the majority determining the action.
- In the event of failure of a milestone exam, students may be allowed a maximum of one further attempt to pass the examination if approved by the examination committee.
- Students must complete a dissertation of original research, judged by the exam committee as a significant and high-quality contribution to the field.
- Students must defend the dissertation within four years of passing the preliminary examination, though programs may request an extension if justified.
- Continued enrollment requires adequate progress to degree, reviewed annually by advisor and DGS, with no more than two semesters of approved leave of absence.

Only a few special provisions need to be made for the joint PhD program, consistent with those provisions made for Duke's current joint PhD program in German with UNC:

- Registration: For Duke students, registration follows the rules of Duke Graduate School; for Duke-NUS students, registration follows the rules of NUS as approved for Duke-NUS.
- Milestone examination committee composition: For Duke students, a majority of members must be Duke faculty; For Duke-NUS, at least one member must be Duke faculty and at least one must be NUS faculty. (Faculty membership as defined by primary academic appointment.

## Oversight and Review

The current excellence in academic standards in the IBM program and continued Duke involvement in the program can be sustained by implementing different tiers of oversight to the program. Importantly, the Duke-NUS IBM PhD program will be formally reviewed every five years for re-evaluation of continued joint sponsorship by Duke University and NUS.

At the highest level, an oversight committee will be formed comprised of senior academic administrators and relevant faculty from both Duke University and NUS (table 15). Proposed members from NUS are the Vice Provost of Graduate Education (co-chair), and the Director of the NUS Graduate School of Interdisciplinary Sciences and Medicine. Committee members from Duke University will be the Associate Dean for Academic Affairs of the Graduate School (co-chair), Associate Dean for Research Training in the School of Medicine, and the faculty liaison to the IBM Program.

The oversight committee will be tasked with orchestrating the formal review of the Duke-NUS IBM PhD program every five years, and informal review annually or as needed. The 5 year review will focus on a) the alignment of the IBM program with both NUS and Duke's training standards, b) the continued high standards of training by the program, and c) Duke University's continued substantial presence at Duke-NUS. This five-year review will form the basis for re-evaluation for joint sponsorship of the IBM PhD program by Duke University and NUS.

In addition, the Associate Dean of Graduate Studies at Duke-NUS will provide the committee with quarterly and annual reports on updates and progress within the program. The annual report will also provide the required information on student learning outcomes assessments.

**Table 15. Oversight Committee for Duke-NUS IBM PhD program**

<b>NUS</b>	<b>Current holder</b>
<i>Vice Provost, Graduate Education (co-chair)</i>	<i>Professor Mohan Kankanhalli, PhD</i>
<i>Director, NUS Graduate School for Integrative Sciences and Engineering (NGS)</i>	<i>Professor Philip Keith Moore, PhD</i>
<b>Duke University</b>	
<i>Associate Dean, Academic Affairs, The Graduate School (co-chair)</i>	<i>Assoc Prof John Klingensmith, PhD</i>
<i>Associate Dean for Research Training</i>	<i>Professor Christopher Nicchitta, Ph.D.</i>
<i>Faculty Liaison</i>	<i>Professor Soman Abraham, PhD Director of Graduate Studies in Pathology Faculty Member, Emerging Infectious Diseases Program at Duke-NUS</i>

## **Establishing a stronger working relationship between Duke University and Duke-NUS**

As mentioned above, a faculty liaison will be appointed who has deep knowledge of both Duke University and Duke-NUS. Currently, Professor Soman Abraham is the ideal candidate to serve as the liaison. Not only is Professor Abraham a renowned and successful researcher but he also serves as the Director of Graduate Studies for the Department of Pathology at Duke University. Thus, he is well versed in the education and training standards of the Duke Graduate School. Furthermore, Professor Abraham has an appointment with the Emerging Infectious Disease Program at Duke-NUS providing him with great knowledge of the research and education programs of the school. Professor Abraham will serve as a member of the oversight committee and serve on the Graduate Program Executive Committee (GPEX).

Furthermore, Associate Dean for Graduate Studies at Duke-NUS, Associate Professor Silke Vogel, will be working closely with the Associate Dean for Research Training at Duke University, Professor Chris Nicchitta, toward creating more opportunities to bring both campuses closer together. Recently, a new exchange program was initiated for students and postdoctoral fellows from Duke or Duke-NUS to work in a collaborating laboratory at the partner institution. The first five grants have just been awarded for this initiative. Other future collaborative opportunities will be explored for Duke faculty to spend time at Duke-NUS. Similarly, Duke-NUS faculty that travel to Duke for research collaborations will be provided with opportunities to become engaged with graduate education during their visit.

### **The faculty liaison to attend the IBM GPEX meetings**

The Graduate Program Executive Committee meets quarterly and is charged with setting the strategic goals of the IBM PhD program, approving guidelines and policies relevant to the program (e.g. graduation policy; PhD qualification exam) and reviews the curriculum to identify additional needs such as new program-specific classes. Furthermore, the committee is charged with approving faculty mentors within the IBM program. Currently committee members include one faculty from each of the respective SRPs and the committee is chaired by the DGS.

Moving forward, Professor Soman Abraham, the current identified faculty liaison, will also participate in these meetings to provide insight and advice. This will not only ensure involvement of Duke faculty but also support the continued alignment between the IBM program and Duke Graduate School.

### **Full time faculty in the Duke Graduate School to participate in the PhD qualifying exam (PQE) and the dissertation defense committee.**

The PQE is an important milestone in the IBM program and aims to ensure that the doctoral student has sufficient knowledge and background needed to proceed towards the PhD degree. The successful completion of the PQE marks a student's transition to the independent research phase of his/her graduate training.

The exam has a similar structure and comparable expectations to what is implemented at Duke University. To further ensure that the PQE continues to conform to Duke standards of doctoral education, the PQE committee composition will be altered moving forward. Currently, the PQE committee consists of four examiners that are faculty at Duke-NUS and approved mentors in the IBM program. To further the alignment of academic standards between Duke and Duke-NUS, each PQE committee will include a full time, full member the Graduate Faculty at Duke University. Duke faculty can participate in the exam via skype/webex. Furthermore, the dissertation defense committee will similarly include a full time faculty of the Graduate Faculty at Duke University in addition to the approved IBM mentors and an outside non-Duke-NUS expert.

**9. A statement of support from the dean of the sponsoring school and any additional clearance obtained or required.** This revised proposal was approved by the Duke-NUS Academic Research Council on November 11, 2015. In November and December 2015, it was subsequently reviewed and approved by the Executive Committee of the Graduate Faculty, the Dean of The Graduate School, the Academic Programs Committee, and the Provost of Duke University. Additional summary information was added to the proposal per the recommendations of APC, to assist Academic Council in their consideration (the executive summary, and a summary of Duke Graduate School requirements for PhD students that will be met by Duke-NUS as well as Duke students). The proposal is also being considered by the faculty governance process at NUS at this time. A statement of support for the joint degree concept from the NUS Vice Provost for Graduate Education is attached.

**10. Assessment of student learning outcomes.**

**PhD Training Program in Integrated Biology and Medicine (IBM) at Duke-NUS  
Graduate Medical School Singapore**

**Outcomes**

1. For graduate students to develop the knowledge, attitudes and critical thinking skills to become independent scientists of biomedical research.
2. For graduate students to develop into competitive candidates for career positions in industry, academia or governmental organizations.

**Specific Measurable Objectives**

1. To enable our graduate students to develop the knowledge, attitudes and critical thinking skills to become independent scientists in the area of biomedical research. At the end of the program the student is expected to be able to:

1. Explain scientific principles in the area of biomedical sciences.
2. Demonstrate mastery in his/her disease research area of study.
3. Explain the basic principles of responsible conduct in research.
4. Contrast the literature in his/her research field.
5. Specify newly developed research methods.
6. Analyze data appropriately to draw the correct conclusions.
7. State clear, testable hypotheses for his/her research.
8. Design experiments and conduct them to test a hypothesis.
9. Interpret results from his/her research with the correct outcome.
10. Recommend further research approaches based on the analysis and interpretation of data.
11. Present his/her research in a scientifically appropriate manner.
12. Write a research paper in the accepted scientific style.
13. Discuss recent advances in his/her research field.

2. To enable our students to develop into competitive candidates for career positions in industry, academia or governmental organizations. At the end of the program the student is expected to be able to:

1. Design his/her experiments independently of the mentor.
2. Critique research presentations given at seminars or conferences.
3. Generate new hypotheses and novel research objectives based on his/her thesis research.
4. Produce an original research publication.

5. Differentiate scientific publications by quality.
6. Produce high-level scientific presentations at national and international meetings
7. Discuss career track options with peers and mentors.
8. Formulate a career plan for his /her career.

### **Assessment methods to measure outcomes**

The Office of Graduate Studies initiates, facilitates, monitors and evaluates the assessments of each graduate student throughout the different stages in the IBM PhD program. The assessment approaches differ depending on the year of study and range from course work performance to bi-annually assessment by their mentors and thesis advisory committees to the thesis evaluations. Throughout the program the students are required to participate in the weekly student research seminar and meet with their thesis advisory committee (TAC) every six months. Further, bi-annually, the faculty is formally asked to discuss with the student, his/her strengths, and the status of the research project and areas of improvements. Current assessment forms are attached as a PDF file.

The two overarching goals for our graduate students are to enable them to:

1. Progress into successful scientists with deep knowledge and critical thinking skills in the field of biomedical research.
2. Develop into competitive candidates for career positions in industry, academia or governmental organizations.

**Table 1** below provides an overview of the core learner objectives, the educational instructional methods applied and evaluation methods used for each objective.

**Table 1: Core learner objectives, educational methods and evaluation approach.**

Year 1 students		
Objectives: By the end of the first year the graduate student will have shown to be able to:	Educational Method	Evaluation Approach
Explain basic principles in the area of biomedical sciences	Foundation class- 'Molecules to Medicines' <ul style="list-style-type: none"> <li>▪ Lecture</li> <li>▪ Class discussion</li> <li>▪ Student presentation</li> </ul>	<ul style="list-style-type: none"> <li>• Performance on exams</li> <li>• Contribution to class discussion (rubric scoring)</li> <li>• Presentations during class</li> </ul>
Explain the basic principles of responsible conduct in research	Responsible Research Conduct <ul style="list-style-type: none"> <li>▪ Lectures</li> <li>▪ Facilitated discussions</li> <li>▪ Case Studies</li> </ul>	<ul style="list-style-type: none"> <li>• Complete course work</li> <li>• Faculty feedback</li> <li>• Assessment of case study discussions</li> </ul>
Demonstrate advanced knowledge in his/her disease research area of study	SRP specific class <ul style="list-style-type: none"> <li>▪ Lectures</li> <li>▪ In-class student presentations</li> </ul>	<ul style="list-style-type: none"> <li>• Performance on exams</li> <li>• Overall grades for class work</li> </ul>
Identify the area of his/her thesis research	Three laboratory rotations in at least two different SRPs	<ul style="list-style-type: none"> <li>• Lab rotation evaluations (written) by the faculty and</li> </ul>

		discussion with students on strengths and area of improvements <ul style="list-style-type: none"><li>• Successful identification of a research laboratory for thesis research</li></ul>
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**Table 1 (continued)**

Year 2 Students		
Objectives: By the end of the second year the graduate student will have shown to be able to:	Educational Method	Evaluation Approach
Differentiate scientific principles in the area of biomedical sciences	PhD qualifying exam (PQE) <ul style="list-style-type: none"> <li>• Written and oral</li> </ul>	<ul style="list-style-type: none"> <li>• PQE results and faculty feedback</li> <li>• Observation by Associate Dean</li> </ul>
Specify newly developed research methods	PhD qualifying exam (PQE) <ul style="list-style-type: none"> <li>• Written and oral</li> </ul> Student Research Seminar <ul style="list-style-type: none"> <li>• Presentation</li> <li>• Discussion</li> </ul>	<ul style="list-style-type: none"> <li>• Results from PQE</li> <li>• Feedback by the PQE chair</li> <li>• Evaluation of presentation</li> </ul>
State a clear testable hypothesis and aims for a research question	PhD qualifying (PQE) exam <ul style="list-style-type: none"> <li>• Written and oral</li> </ul> Lab meetings Thesis advisory committee	<ul style="list-style-type: none"> <li>• Results from PQE</li> <li>• Feedback by the PQE chair</li> <li>• Advisor and Committee evaluation</li> </ul>
Year 3-5 Students		
Objectives: At the end of the program the student will have shown to be able to:	Educational Method	Evaluation Approach
Discuss and critique recent advances in his/her research field	Student Research Seminar Thesis advisory committee	<ul style="list-style-type: none"> <li>• Observation</li> <li>• Faculty evaluation</li> <li>• TAC member evaluation and written report (bi-yearly)</li> </ul>
Analyze research data appropriately and draw the correct conclusions.	Thesis advisory committee (TAC)	<ul style="list-style-type: none"> <li>• TAC member evaluation and written report (bi-yearly)</li> </ul>
Formulate appropriate research approaches based on the analyses and interpretation of data	Lab and research program meetings Student Research Seminar Thesis advisory committee (TAC)	<ul style="list-style-type: none"> <li>• Mentor feedback</li> <li>• Faculty Evaluation</li> <li>• TAC member evaluation and written report (bi-yearly)</li> </ul>
State clear, testable hypotheses, design and execute experiments appropriately to test the stated hypothesis.	Thesis advisory committee (TAC) Thesis Defense Dissertation	<ul style="list-style-type: none"> <li>• TAC member evaluation and written report (bi-yearly)</li> <li>• Oral &amp; written evaluation by thesis defense committee</li> <li>• Approval of dissertation</li> </ul>
Present his/her research in a scientific manner	Student Research Seminar Thesis Defense	<ul style="list-style-type: none"> <li>• Faculty evaluation</li> <li>• Public dissertation defense</li> </ul>
Critique research presentations appropriately at seminars or conferences.	Student Research Seminar Conferences	<ul style="list-style-type: none"> <li>• Observation and faculty evaluation</li> <li>• Feedback by mentor</li> </ul>

**Table 1 (continued)**

Year 3-5 Students		
Objectives: At the end of the program the student will have shown to be able to:	Educational Method	Evaluation Approach
Produce an original research publication written in the appropriate scientific style and submitted to an international peer-reviewed journal in the relevant research area.	Publication	<ul style="list-style-type: none"> <li>• Manuscript under review, in revisions or accepted for publication</li> </ul>
Produce high-level scientific presentations at national and international meetings	Attendance of conferences Research presentations	<ul style="list-style-type: none"> <li>• Feedback on presentation (oral or poster presentation)</li> </ul>
Discuss career track options with peers and mentors	Discussions	<ul style="list-style-type: none"> <li>• Faculty Feedback</li> <li>• Updated CV</li> </ul>
Formulate a plan for his/her career	Individual Development Plan (IDP) Discussions	<ul style="list-style-type: none"> <li>• Annually Updated IDP</li> <li>• Participating in workshops organized by career development program (CDeP)</li> <li>• Updated CV</li> </ul>