Concurrent Master’s in Genomic Medicine for Medical Students
4 years to MD/MS

Jeffery M. Vance, PhD, MD
Professor, Dr. John T. Macdonald Foundation Department of Human Genetics
Professor of Neurology
John P. Hussman Institute for Human Genomics
University of Miami
There is a great need for broad physician training in genomics

**Experience:** Genomedical Connection early 2000’s
- Primary care practices in Guilford Co., NC
- **Goal:** increase awareness in PCP of need for referral to genetic services
- Computerized self-reported family history (MeTree)

**Difficulty in Educating Practicing Physicians**
- Competing versus their clinical time and specialty training
- Competing against what GM applications are available to them now
- Concern about liability
Focused on Medical Students

- In a learning environment
- Can act as trainers themselves over 8 years of training
- Train for the future when there are more GM opportunities
Medical curriculum is full – where can additional genomic content be added?
MBL – Medical Genetics (33 hours)

- Genetic variation & mutation
- Pathophysiology
- Not covered: ‘precision medicine,’
  ethics, GENOMICS, technologies, the
  application of genomics, complex
  genetics
- Clinical case presentations (x 4)
- Metabolic disorders
- Pharmacogenetics
- Neurodevelopmental disorders, auditory system disorders
MD/MS curriculum

Students earn MS concurrently with MD, graduating in four years with both degrees.

- Focused on clinical application
- Understanding the concepts of genomic medicine.
- Create a foundation of knowledge for future discoveries

Parallel approach

- Avoids problem with space in MD curriculum
- Less intense course schedule/infrastructure to develop compared to an additional 1-2 years of training
- Minimal added cost and time for students
- Learning continues up to residency
- Gives time for questions and hopefully reinforces training
MD/MS program

Additional Advantages

- Increases the strength of their residency application
- Increases awareness in other medical students and Attendings over 4 years
- Training others through the students

Goal is create a qualified consumer and advocate
Student Recruitment

- Advertise program but acceptance to MD and MS are independent
- First semester Introduction
- Application to MS program in the first semester
- Approval by Medical School
  - 10-12 students
  - Start Classes in 2\textsuperscript{nd} Semester of First year

Advertise program but acceptance to MD and MS are independent
Blended modes of instruction

“Flipped classroom”: Didactic content online
- Inspired by student habits with MD lectures
- 50% of hours

In person small group discussion 1-2x/week
- Case study, problem based learning, discussions of literature
- Team teaching when possible
- 50% of hours
MSGM Curriculum: 4 Themes

Ethics
- Genome Ethics and Public Policy
- Research Ethics and RCR

Basic Genomic Principles and Concepts
- Clinical Applications I

Genomic technology, analysis and interpretation
- Genomic Medicine Laboratory
- Computational Methods for Genomic Medicine

Clinical applications
- Clinical Applications II
- Clinical Applications III
- Genomic Medicine Clerkship

Capstone Experience
# MSGM Curriculum

<table>
<thead>
<tr>
<th>Year 1 (second semester)</th>
<th>Year 2</th>
<th>Years 3 &amp; 4</th>
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<tbody>
<tr>
<td><strong>Clinical Applications of Genomic Medicine I</strong>: The Clinical Applications of Genomic Medicine series provides genomic medicine case studies and systems-based learning paralleling the medical school core curriculum.</td>
<td><strong>Computational Methods for Genomic Medicine</strong>: Provides instruction on basic biostatistical terminologies and tests as well as risk assessment and bioinformatics tools.</td>
<td><strong>Genomic Medicine Clerkship</strong>: An elective clerkship in genomic medicine or medical genetics completed as part of the MD curriculum.</td>
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<td><strong>Genome Ethics and Public Policy</strong>: A case-based approach to discussing ethical, legal and social issues related to genomic medicine.</td>
<td><strong>Clinical Applications of Genomic Medicine II &amp; III</strong>: Topics covered include respiratory system, nephrology, gastroenterology and nutrition.</td>
<td><strong>Journal Symposiums</strong>: Students meet five times a year to discuss new papers in the field, present at least once a year.</td>
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<td><strong>Research Ethics</strong>: Prior to research practicum, training in the responsible conduct of research, protection of human subjects, and obtaining regulatory approval.</td>
<td><strong>Genomic Medicine Laboratory</strong>: Students rotate through the molecular genetics and biochemical genetics diagnostic laboratories and gain hands-on experience with interpretation of whole-exome and whole-genome sequencing results.</td>
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**Capstone Experience**
Mentored Research Project

Any subject with genetics, genomics

10 Case Reports

Describe case, potential for genomics (whether done or not), results and outcomes

Genomic Medicine Education (GME)

Mini-symposium 5 times per year, present at least once a year

Capstone Experience

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<td>Research (40hrs)</td>
<td>GM Case Reports (40 hrs)</td>
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<td>Journal Presentations (GME)</td>
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<tr>
<td>Research Presentation</td>
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Laboratory Research Experience

Identify causal genes using local families with rare, syndromic phenotypes

 Started as “optional” enrichment opportunity
  – Most of students ended up participating

 Incorporated into core laboratory course in 2015
  – Students wanted more hands on data
  – Good concept of what test results mean for NGS
  – Can do this on computer, so time is flexible
Laboratory Course

- Raw Data Analysis
  - Image processing and base calling
- Whole-Genome Mapping
  - Alignment to reference genome
- Variant Calling
  - Detection of genetic variation (SNPs, Indels, SVs)
- Relevance
  - Linking variants to biological information
Impact of Laboratory Experience

Key point: motivation to do the work => clinical relevance & utility

– Better than analyzing own sequence (w/attendant issues)
  • Contrasted with experience reported by Sanderson et al., 2015
– Much better than analyzing public data (> impact)
– Exposed to programs, websites and databases they can use in future practice
Examples of Laboratory Research course

- Macrothrombocytopenia families - MYH9 mutations identified
- Intellectual disability with microcephaly families
- MMIH syndrome without ACTG2 mutations
- Dyskeratosis congenita/undiagnosed disease
Examples of Capstone Research Projects

€“ “Literature review on the Genomic Medicine in Preventive Cardiology”

€“ “Review of risk factors for contralateral breast cancer”

Original Investigation

Driver Mutations in Uveal Melanoma Associations With Gene Expression Profile and Patient Outcomes

Christina L. Decatur, BS; Erin Ong, BS, BA; Nisha Garg, BS; Hima Anbunathan, MS; Anne M. Bowcock, PhD; Matthew G. Field, MS; J. William Harbour, MD

Breast Cancer in Africa: Limitations and Opportunities for Application of Genomic Medicine

Allison Silverstein, 1, 2, 3, 4, *Rachita Sood, 1, 2, 3 and Ainhoa Costas-Chavarrí 1, 2, 4

1Department of Plastic and Oral Surgery, Boston Children's Hospital, Boston, MA 02115, USA
2Harvard Medical School, Program in Global Surgery and Social Change, Boston, MA 02115, USA
3University of Miami Miller School of Medicine, Miami, FL 33136, USA
4Rwanda Military Hospital, Kigali, Rwanda
*Allison Silverstein: Email: allison@allisonsilverstein.com
Academic Editor: Lei Shi
Conference attendance can significantly shape program outcomes
Intermediate Outcomes lead to opportunities

One student (Allison Silverstein) just completed a Paul Farmer fellowship for one year, working in Rwanda and Zambia

- Inspired by Why We Can’t Wait Conference
- Worked on setting up surgical programs for Zambian government with WHO [http://www.allisonsilverstein.com/](http://www.allisonsilverstein.com/)

Adventures Abroad: Rwanda and Beyond
DON'T JUST TEACH A MAN TO FISH, GO FISHING WITH HIM.
Intermediate outcomes

good to excellent satisfaction with courses

- Changed laboratory course to current structure
- Data analysis course reoriented to bioinformatics/sequence data
- Ethics courses rated very important and effective
- Clinical applications courses more positive reviews than basic concepts, asked for more clinical topics
- Flipped classroom works; small group discussion is key and most popular.
Intermediate outcomes
student confidence in genetic knowledge

- Students report increased confidence in genetic knowledge as they enter clinical rotations
- Report increased sharing of genetic knowledge with peers in MD classes
  - Some non-MSGM students express wish that these topics were taught to all students
  - Some MSGM students report concern that their peers are *not* learning these topics
  - Some report errors in their normal lectures on genetic content
- Students have increasing number of interactions with attendings/residents pointing out genetic aspects of cases
Longer-term outcomes

- Impact of MSGM on knowledge, beliefs and attitudes at end of program (starting 2016)
- Assessment of residency choices (2016)
- Evaluation of perceived impact on clinical practice
  - Residency (2016) - the 4 graduated students matched on 1st or 2nd choice.
    - All indicated MSGM was a very positive factor in their interviews and matching
Barriers to meeting objectives and potential solutions

- Student time during medical school courses
  - Package material for flexible completion
  - Use valuable (limited) class time for interaction and active learning

- Additional financial costs of second degree
  - Scholarship, grant funding
Barriers to meeting objectives and potential solutions

Faculty time and commitment
- Small group format requires more instructors
- Incentivize mentors for capstone

Capacity
- Restrict enrollment to 10-12
- Increased faculty involvement would expand capacity
**Students**

Program Growth each year

<table>
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<tr>
<th>Year</th>
<th>Students</th>
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<tr>
<td>2013</td>
<td>5</td>
</tr>
<tr>
<td>2017</td>
<td>47</td>
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**Funding**

- Currently self-supporting on tuition
- John T. and Winifred Hayward Foundation first 3 years
- Hayward support continues for
  - Capstone Research support
  - Family medicine project
  - Travel funds to attend meetings (students)
Future directions

Genomic medicine initiative in Family Medicine Clinics
- Provide additional clinical experience to MSGM students
- Add to the existing Medical Genetics clinical rotation

Potentially extend MSGM curriculum to other audiences (residents, fellows)
- Need to determine how to package materials for more heterogeneous audiences
- Retaining small group component
- Capacity of faculty and training opportunities?
Conclusions (after 4 years)

- Active learning strategies are key to program success
  - Different from didactic lectures
  - Teaching students to evaluate the support for a test or treatment decision

- Laboratory data exercises that have clear clinical utility (and publication potential) improve enthusiasm

- Journal discussions in 3\textsuperscript{rd} and 4\textsuperscript{th} years key to keeping students up-to-date

- Have to be able to adapt and change as med school changes
Conclusions

Students are very interested in genomic medicine
– Recognize this as “wave of the future”
– Like being in the vanguard
– Perceive an advantage for residency matching
– Like being able to share knowledge with peers
– However, they are disappointed when reach clinics in the lack of knowledge and opportunities in applying GM by their current Clinical Attendings
– Hopefully as residents they will be help educate and lead the use of GM and become knowledgeable Attendings.
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