

THE SCIENCE AND SOCIAL IMPACT OF EMERGING MEDICAL TECHNOLOGIES

House Course
SPRING 2022

INSTRUCTOR INFO

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OFFICE HOURS

By Request, Location TBD

FACULTY SPONSOR

Cameron Kim, Ph.D.

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Department of Biomedical Engineering

<https://bme.duke.edu/faculty/cameron-kim>

MEETING TIME

Mondays

5:15 – 6:45

LINK 059 (Seminar 1)

“To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science”

Albert Einstein

COURSE DESCRIPTION

The last 100 years have seen a revolution in the ways in which we treat human health, from the application of X-Rays as a diagnostic tool, to the creation of antibiotics, to the development of chemotherapy, it is safe to say that the current standards of healthcare have enabled us to diagnose and treat patients to a level that has no parallel in human history. What’s exciting is that this medical revolution continues to accelerate with new technologies that promise to raise the bar of healthcare ever higher! However, at the forefront of these new avenues of clinical treatment come new questions regarding the moral and socioeconomic consequences of such rapid advancement. As we inch closer to the grand goal of solving all medical ailments, we must reflect on the inequality within medicine and the progress that is still to be made.

This course is an introduction to major technological advancements in medicine that are currently revolutionizing patient care (or will be in the near future), and a discussion of the social, ethical, and health equality implications of these advancements. The content will span Regenerative Medicine (iPSCs, Anti-Aging Technology, Brain Machine Interfaces), Personalized Medicine (Immunotherapy, whole genome sequencing, CRISPR/Cas9), and High-Performance Diagnostic Tools (Low-Cost/Low-Volume Diagnostic Tests, Wearable Monitoring Devices, Imaging Modalities). The course will provide students with the foundational knowledge to evaluate these technologies and then foster discussion surrounding the societal and moral questions that arise around the widespread application of these technologies. We hope to equip the students of this course to be educated, scientific citizens as these technologies become more relevant over our lifespans and lead them down a path of perpetual inquiry and ethical curiosity.

COURSE STRUCTURE

The course is subdivided into the following sections:

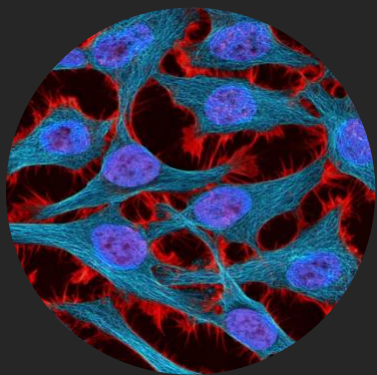
1. Introduction (Week 1)
2. Personalized Medicine (Weeks 2-5)
3. Regenerative Medicine (Weeks 6-8)
4. High Performance Diagnostic Tools (Weeks 9-12)
5. Conclusion (Week 13)

We’ll be guiding the class through this exploration of different areas of technology spending time with each topic building an understanding of fundamental theory and then diving into discussions of the implications of the technology.

Through the course the students will be exposed to navigating the scientific literature, news articles and supplementary texts. No heavy prerequisite knowledge is required, and we invite students of all backgrounds to participate.

LEARNING OBJECTIVES

- Develop an understanding of specific novel medical technologies and the basics of how they work
- Appreciate the time and resources that are poured into development of medical technologies and the resulting interests surrounding them
- Engage in discussions surrounding the social impact and ethics of medical technologies
- Assess the potential of emerging technologies to increase and/or reduce socioeconomic inequalities
- Evaluate how scientists, patients, and average people can engage with and leverage medical breakthroughs for the global good



FAQ

WHY ARE THESE TECHNOLOGIES IMPORTANT?

The novel technologies bring with them potentially paradigm-shifting implications for personalized medicine, regenerative medicine, diagnostic tools, and medicine. These technologies aim to improve patient outcomes, increase accessibility to medicine, and further our understanding of human physiology which could lead to longer, healthier lives for more people, better quality of living, lower economic burden of healthcare, and future technological advancements - they promise to push our society forward.

WHY MUST WE DISCUSS THEM?

Unbridled development may engender and amplify health disparities and existing social issues which may have negative effects on millions and billions of people around the world. This makes it so important to have an educated and well-informed populace and leaders who will be open to discussing and alleviating the socioeconomic implications of these technologies.

DO I NEED TO HAVE A BACKGROUND IN SCIENCE?

You do not! Though a general familiarity with scientific methods and technologies will aid in understanding the content, a background in medicine, biology, engineering, research, and related content is not assumed. We will be breaking down the technologies in a digestible manner while supplementing your knowledge with readings, articles, and videos to improve your learning. We will also be available as resources throughout the course to help you in understanding concepts presented in the course.

COURSE REQUIREMENTS

House Courses are graded on the S/U basis. A grade of satisfactory in this course requires satisfactory completion of all assignments of this course including written and oral assignments, attendance, and in-class discussions. Students are expected to complete weekly reading prior to attending class to fully engage in the lecture and proceeding discussion. Students are required to attend at least 11 classes to receive a passing grade. If a student is planning to miss a lecture, guest speaker, or field trip they must let the instructors know of their conflict in advance. Each student is encouraged to engage with the material in a manner most suitable to their learning preferences and needs.

WRITING ASSIGNMENT

House Courses require one or more scholarly papers totaling approximately 1500 words in length, or the equivalent of five (5) double spaced pages. We require 2 papers, each 750 words, in length that will be due one at the midpoint of the semester and one towards the end.

Prompt 1: Select an older scientific article (pre-2010) describing a medical technology. In at least 750 words, provide a summary of the article including a basic explanation of what the technology is, what it aims to do, and how it works. Include some of the strengths and weaknesses of the technology and a discussion on the moral and socioeconomic questions raised by the breakthrough. Finally, the paper should analyze the effect this technology has had since the time of the article, has it lived up to what the creators hoped for?

Prompt 2: Select a scientific article describing a novel medical technology. In at least 750 words, provide a summary of the article including a basic explanation of what the technology is, what it aims to do, and how it works. Include some of the strengths and weaknesses of the technology and a discussion on the moral and socioeconomic questions raised by the breakthrough. Finally, the paper should discuss how you envision it revolutionizing the future of healthcare.

DIVERSITY AND INCLUSIVITY STATEMENT

A fundamental motivation of this course is to promote diversity and inclusivity of all individuals and open expression of their ideas within this course. Due to the sensitive and often personal nature of the course's material, respect is essential for the success of the class. We expect that members of the class will express this level of understanding and respect to their fellow classmates and instructors.

ACCOMODATIONS FOR STUDENTS WITH DISABILITIES

If you are a student with learning needs and/or require special accommodations, please let us know what we can do to make you feel comfortable.

DUKE COMMUNITY STANDARD

As a reminder of Duke's Community Standard:

"Duke University is a community dedicated to scholarship, leadership, and service and to the principles of honesty, fairness, respect, and accountability. Citizens of this community commit to reflect upon and uphold these principles in all academic and nonacademic endeavors, and to protect and promote a culture of integrity.

To uphold the Duke Community Standard:

- I will not lie, cheat, or steal in my academic endeavors;
- I will conduct myself honorably in all my endeavors; and
- I will act if the Standard is compromised."



INSTRUCTOR BIOS

JONATHAN PERERA, P' 22

Hey! I'm a senior majoring in Biomedical Engineering and minoring in Chemistry on the pre-med track. From my early days of childhood, I've always harbored a curiosity and love for scientific learning. This first manifested itself as an obsession with sharks back when I lived in Sri Lanka and has grown to now include immunology, imaging, optics, bioinformatics, and genomics amongst others. I have been heavily involved in research at Duke, The Mayo Clinic, and the Mass. General Wellman Center for Photomedicine and I am aiming for an MD/PhD! I am extremely excited to share the intricacies and beauty of these inspiring medical technologies with you through this course with my co-instructor Ayden! And a fun fact is that I'm midway through my training for a pilot's license!

AYDEN CASE, T' 22

Hello! I'm a senior studying Chemistry with plans to earn an MD and PhD after graduation. I am interested in immunology, specifically in the context of heart disease and immunotherapy development. At Duke, I have conducted research in the lab of Dr. Ravi Bellamkonda examining the brain's immune microenvironment and response to cell-mediated immunotherapies. I have also led clinical research focused on disparities in healthcare access and surgical outcomes, with a specific emphasis on the Native American community. I also conducted research into stem cell technology at Stanford's Institute for Stem Cell Biology and Regenerative Medicine over the summer of 2021. I am excited to bring my lessons from the lab to this course, as well as learn from you all and your experiences!

FACULTY SPONSOR: DR. CAMERON KIM

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GUEST SPEAKERS

We are excited to have the privilege of having several notable guest speakers and/or their colleagues coming to present to the class throughout the semester. This includes:

- **Charles A. Gersbach, PhD**
Gene Editing: CRISPR/Cas9
Professor of Biomedical Engineering
Duke University
- **Conor L. Evans, PhD**
AI in Medical Imaging
Associate Professor at the Harvard Medical School
Wellman Center for Photomedicine at Massachusetts General Hospital
- **Albert Y. Wu, MD, PhD, FACS**
Regenerative Medicine
Associate Professor of Ophthalmology
Stanford University Healthcare
- **Buz Waitzkin, JD**
The Duke Science Regulation Lab
Deputy Director, Duke Initiative for Science & Society.
Duke University

ASSIGNED READING

Excerpts from the following will be assigned for reading throughout the semester:

Books

1. CRISPR People: The Science and Ethics of Editing Humans, Henry T. Greely. The MIT Press; 1st edition (February 16, 2021)*
2. The Immortal Life of Henrietta Lacks. Rebecca Skloot. Crown (March 8, 2011)*
3. Sapiens: A Brief History of Humankind. Yuval Noah Harari. Harper Perennial; Reprint edition (May 15, 2018)
4. Introduction to Biomedical Instrumentation: The Technology of Patient Care. Barbara L. Christie. Cambridge University Press; 2nd edition (December 27, 2017)
5. Medical Imaging: Signals and Systems. 2nd Editions. Jerry R. Prince, Jonathan M. Links. Pearson (2015).
6. Zero to One. Peter Thiel. Random House (January 1, 2014).
7. Deep Medicine: How Artificial Intelligence Can Make Healthcare Human Again. Eric Topol. Basic Books; Illustrated edition (March 12, 2019)
8. Immunobiology. Kenneth Murphy, Casey Weaver. Garland Science; 9th edition (2016)
9. Everybody Wants to Go to Heaven but Nobody Wants to Die: Bioethics and the Transformation of Health Care in America. Amy Gutmann, Jonathan D. Moreno. Liveright; 1st edition (August 27, 2019)
10. Bioethics: Principles, Issues and Cases. Lewis Vaughn. Oxford University Press (2020).

* - we recommend obtaining a copy

See next page for assigned articles.

Articles

All articles may be accessed through Duke University Libraries or will be provided to students. Additional articles may be sent to students for supplementary reading.

1. Personalized Medicine

- a. Pickar-Oliver, A., Gersbach, C.A. The next generation of CRISPR–Cas technologies and applications. *Nat Rev Mol Cell Biol* 20, 490–507 (2019) <https://doi.org/10.1038/s41580-019-0131-5>
- b. Anderson, D., Baynam, G., Blackwell, J.M. et al. Personalised analytics for rare disease diagnostics. *Nat Commun* 10, 5274 (2019). <https://doi.org/10.1038/s41467-019-13345-5>
- c. Genetic Engineering Will Make Income Inequality Much Worse. (<https://www.forbes.com/sites/eriksherman/2017/08/20/genetic-engineering-will-make-income-inequality-much-worse/>)
- d. Yang Y. Cancer immunotherapy: harnessing the immune system to battle cancer. *J Clin Invest*. 2015 Sep;125(9):3335-7. doi: 10.1172/JCI83871. Epub 2015 Sep 1. PMID: 26325031; PMCID: PMC4588312.
- e. Riley RS, June CH, Langer R, Mitchell MJ. Delivery technologies for cancer immunotherapy. *Nat Rev Drug Discov*. 2019 Mar;18(3):175-196. doi: 10.1038/s41573-018-0006-z. PMID: 30622344; PMCID: PMC6410566.
- f. Sahin U, Karikó K, Türeci Ö. mRNA-based therapeutics--developing a new class of drugs. *Nat Rev Drug Discov*. 2014 Oct;13(10):759-80. doi: 10.1038/nrd4278. Epub 2014 Sep 19. PMID: 25233993.

2. Regenerative Medicine

- a. Shi Y, Inoue H, Wu JC, Yamanaka S. Induced pluripotent stem cell technology: a decade of progress. *Nat Rev Drug Discov*. 2017 Feb;16(2):115-130. doi: 10.1038/nrd.2016.245. Epub 2016 Dec 16. PMID: 27980341; PMCID: PMC6416143.
- b. Scudellari, M. How iPS cells changed the world. *Nature* 534, 310–312 (2016). <https://doi.org/10.1038/534310a>
- c. Yap, K.K. (2016), Inequality Issues in Stem Cell Medicine. *STEM CELLS Translational Medicine*, 5: 265-266. <https://doi.org/10.5966/sctm.2015-0232>
- d. Lo B, Parham L. Ethical issues in stem cell research. *Endocr Rev*. 2009;30(3):204-213. doi:10.1210/er.2008-0031
- e. Wyss-Coray T. Ageing, neurodegeneration and brain rejuvenation. *Nature*. 2016 Nov 10;539(7628):180-186. doi: 10.1038/nature20411. PMID: 27830812; PMCID: PMC5172605.
- f. Schmeer C, Kretz A, Wengerodt D, Stojiljkovic M, Witte OW. Dissecting Aging and Senescence-Current Concepts and Open Lessons. *Cells*. 2019 Nov 15;8(11):1446. doi: 10.3390/cells8111446. PMID: 31731770; PMCID: PMC6912776.
- g. Nicolelis MA. Brain-machine interfaces to restore motor function and probe neural circuits. *Nat Rev Neurosci*. 2003 May;4(5):417-22. doi: 10.1038/nrn1105. PMID: 12728268.
- h. O'Doherty JE, Lebedev MA, Ifft PJ, Zhuang KZ, Shokur S, Bleuler H, Nicolelis MA. Active tactile exploration using a brain-machine-brain interface. *Nature*. 2011 Oct 5;479(7372):228-31. doi: 10.1038/nature10489. PMID: 21976021; PMCID: PMC3236080.

3. High Performance Diagnostic Tools

- a. Exclusive: How Elizabeth Holme's House of Cards Came Tumbling Down. Nick Bilton, *Vanity Fair*. September 26th, 2016. (<https://www.vanityfair.com/news/2016/09/elizabeth-holmes-theranos-exclusive>)
- b. Diagnostic: Frontiers in Blood Testing. Emily Sohn. *Nature* 28 September 2017. <https://www.nature.com/articles/549S16a>
- c. Inspired by a Whirligig toy, Stanford bioengineers develop a 20-cent, hand-powered blood centrifuge. (<https://news.stanford.edu/2017/01/10/whirligig-toy-bioengineers-develop-20-cent-hand-powered-blood-centrifuge/>)
- d. Gnoth C, Johnson S. Strips of Hope: Accuracy of Home Pregnancy Tests and New Developments. *Geburtshilfe Frauenheilkd*. 2014;74(7):661-669. doi:10.1055/s-0034-1368589
- e. Apple Plans Blood-Pressure Measure, Wrist Thermometer in Apple Watch. <https://www-wsj-com.proxy.lib.duke.edu/articles/apple-plans-blood-pressure-measure-wrist-thermometer-in-watch-11630501201>
- f. Vandenberg, O., Martiny, D., Rochas, O. et al. Considerations for diagnostic COVID-19 tests. *Nat Rev Microbiol* 19, 171–183 (2021). (<https://doi.org/10.1038/s41579-020-00461-z>)
- g. Ibrahim A, Gamble P, Jaroensri R, Abdelsamea MM, Mermel CH, Chen PC, Rakha EA. Artificial intelligence in digital breast pathology: Techniques and applications. *Breast*. 2020 Feb;49:267-273. doi: 10.1016/j.breast.2019.12.007. Epub 2019 Dec 19. PMID: 31935669; PMCID: PMC7375550.

4. General Topics

- a. The future of medicine. Outlook (Collection of Articles). *Nature*. 8th March 2018. <https://www.nature.com/collections/zfnjwhjct/>
- b. From reproduction to the right to die: bioethics now. Eric J. Topol. *Nature*. 13th August 2019 <https://doi.org/10.1038/d41586-019-02412-v>

INTRODUCTION

Week 1 Topic: **Introduction**

1/10

Faculty Sponsor attending (Dr. Cameron Kim)

Activity/Discussion:

Group Forum: What do you think is the most impactful medical breakthrough we will see in our lifetime? What will be more significant from this development: the impact on health, or the impact on our society?

Assignments:

Prepare a short blog post (150 words) describing your takeaways from the group forum. Brainstorm which category of treatment you'd like to research in-depth.

Readings:

CRISPR People (Chp 1: pgs 1-48),
Article (1a, pgs 1-18)

--- Martin Luther King Jr. Day ---

PERSONALIZED MEDICINE

Week 2 Topic: **Personalized Medicine: Whole Genome Sequencing/Genetic Testing**

1/24

Faculty Sponsor attending (Dr. Cameron Kim)

Activity/Discussion:

Group Activity: In groups of 3-4, discuss the ethical considerations surrounding companies like 23&Me and Ancestry.com. Should these companies release health/disease data with their results? Would you use such a company? Summarize your conclusions and present your opinions to the class.

Assignments:

Assign group presentation teams based on common, brainstormed interests and blog post contents from previous class.

Presentation Guidelines: Prepare a 4-5 slide, 10-12 minute presentation about an application of one of the course's three overarching themes in the news. What's going on? What are the ethical questions? How should this inform our investigation of the topic?

Readings (# pages):

CRISPR People, (Chp 1: pgs 49-88),
Article (1b, pgs 1-7). Article (1c, online article)

Week 3 Topic: **Personalized Medicine: Immunotherapy**

1/31

Activity/Discussion:

Group Forum: How can an expensive, complex treatment like immunotherapy be made widely accessible? How do the practical constraints of such a therapy limit its effectiveness?

Assignments:

Work on presentations.

Readings (# pages):

CRISPR People, (pgs 201-230), Immunobiology (Chp 1-3, pgs 1-75)
Article (1d, 3335 - 37), Article (1e, 175-195)

Week 4 Topic: **Group Presentations**

2/7

Activity/Discussion:

Group Presentations

Assignments:

Write a short blog post (150 words) summarizing your key takeaways and questions from the group presentations.

Readings (# pages):

CRISPR People, (pgs 230-268),
Article (1f, pgs 759 - 776)

Week 5 Topic: Guest Speaker 1: Science Policy

2/14*

Essay Response #1 due on Monday 2/21

Activity/Discussion:

Guest Speaker Q and A

Assignments:

Work on Essay Response #1

Readings (# pages):

Henrietta Lacks, (Chps 1-5: pgs 17-48), Article (2a, 115-128)

WRITING ASSIGNMENT #1 DUE NEXT CLASS

REGENERATIVE MEDICINE

Week 6 Topic: Regenerative Medicine: Induced Pluripotent Stem Cells

2/21

Essay Response #1 due

Faculty Sponsor attending (Dr. Cameron Kim)

Activity/Discussion:

Group Activity: In groups of 3-4, discuss the potential pitfalls of iPSC harvesting and organoid culture . Would you allow your cells to be turned into iPSC lines? Under what circumstances? Summarize your conclusions and present your opinions to the class.

Assignments:

Find a news article discussing controversy surrounding the use of stem cells. Prepare to share answers to the following questions next class: Where do you fall on the issue? Is there a clear solution? Will this issue persist as the technology develops?

Readings (# pages):

Henrietta Lacks, (Chps 6-9: pgs 49-76),

Article (2b, pgs 310- 312), Article (2c, 256-266), Article (2d, 204-213)

Week 7 Topic: Guest Speaker 2: Regenerative Medicine

2/28

Activity/Discussion:

Guest Speaker Q and A

Assignments:

Write a short blog post (150 words) on your thoughts on the future of regenerative medicine. Is this the next stage of human evolution? What would it mean to be artificially enhanced? How would your life change?

Readings (# pages):

Sapiens (Chps 1-3: pgs 3-63),

Article (2g, pgs 417-422), Article (2h, pgs 228-231)

--- Spring Break ---

Week 8 Topic: Regenerative Medicine: Aging

3/14

Activity/Discussion:

Watch the following Veritasium video and discuss reactions in a group forum:

<https://youtu.be/QRt7LjqJ45k>

Assignments:

Write a short blog post (150 words) summarizing your thoughts on the ethics of anti-aging technology. Are we meant to live forever? What would this technology change about day-to-day life?

Readings (# pages):

Henrietta Lacks, (pgs 77-109),

Article (2e, 180-186), Article (2f, 1-19)

HIGH-PERFORMANCE DIAGNOSTIC TOOLS

Week 9 Topic: High-Performance Diagnostics: Microvolume/Distrib. Blood Tests

3/21

Faculty Sponsor attending (Dr. Cameron Kim)

Activity/Discussion:

Group Activity: In groups of 3-4, discuss the structure of research where money is poured into an idea with no guarantee of a final solution - is this the only avenue of technological progress and novel discoveries? What external factors dictate the field a researcher will pursue? What constitutes good research?

Assignments:

Find an article discussing a novel technology for low-cost or high-throughput diagnostics. Summarize it in a couple of sentences and share it with your classmates.

Readings (# pages):

Zero to One (Chps 1-5: pgs 1-58), Article (3a, online article), Article (3b, pgs S16-S18), Article (3c, online article)

Week 10 Topic: Guest Speaker 3: CRISPR/Cas9

3/28*

Activity/Discussion:

Guest Speaker Q and A

Assignments:

Write a short blog post (150 words) evaluating how a) CRISPR may potentially impact clinical care b) potential societal implications and disparities associated with gene editing.

Readings (# pages):

Deep Medicine (Chps 1-3: pgs 1-58), Medical Imaging (Chp 1: pgs 5-13), Article (3g, 267-273)

Week 11 Topic: High-Performance Diagnostics: Wearables

Essay Response #2 Due on Monday 4/11

Activity/Discussion:

Group Forum: What does your smartphone or smartwatch know about you? Do the privacy concerns surrounding this data collection outweigh the health benefits? How do these expensive products affect health inequalities along socioeconomic lines?

Assignments:

Work on Essay Response #2

Readings (# pages):

Zero to One (Chps 6-9: pgs 59-119), Biomedical Instrumentation (pgs 50 - 69)

Article (3d, pgs 661-669), Article (3e, online article), Article (3f, pgs 171-183)

WRITING ASSIGNMENT #2 DUE NEXT CLASS

Week 12 Topic: Guest Speaker 4: AI in Medicine

4/11

Essay Response #2 Due

Activity/Discussion:

Guest Speaker Q and A

Assignments:

Write a short blog post (150 words) evaluating how a) AI will be incorporated into the clinic over the coming years and their role in assisting clinicians b) Will a human physician always be required?

Readings (# pages):

Everybody wants to go to Heaven (Chps 1-3, pgs 11-84), Bioethics (Chp 1, pgs 3-28), Article (4b)

Week 13 Topic: Conclusion

4/18

Activity/Discussion:

Individual Reflection: Which topics were most striking to you based on their potential to change medicine? Do you think it will have a net positive or net negative goal on equality in our society? How do you feel this course has equipped you to make the change a positive one?

Assignments:

None

Readings (# pages):

Deep Medicine (Chps 4-6: pgs 59-136), Medical Imaging (pgs 50-100), Article (4a) → Article Collection