SLOAN SCHOOL OF MANAGEMENT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Andrew W. Lo **15.482** **Spring 2017**

Healthcare Finance

This course covers the role of finance in the healthcare industry, with particular emphasis on the application of novel financing methods to facilitate drug discovery, clinical development, and greater patient access to high-cost therapies.

Funding for basic science and early-stage translational medicine is becoming scarcer, and at the worst possible time—when we now have the scientific and engineering expertise to make major breakthroughs in our understanding of the molecular basis of many deadly diseases and how to treat or prevent them. The dearth of funding for translational medicine in the so-called "Valley of Death" can be attributed to several factors, but a common thread among them is increasing financial risks in the biopharma industry and greater uncertainty surrounding the economic, political, and academic environments within the biomedical ecosystem. Increasing risk and uncertainty inevitably leads to an outflow of capital as investors and other stakeholders seek more attractive opportunities in other industries.

By applying financial techniques such as portfolio theory, securitization, and derivative securities to biomedical contexts, more efficient funding structures can be developed to reduce financial risks, lower the cost of capital, and bring more life-saving therapies to patients faster.

Topics covered in this course include: basic financial analysis for the life-sciences professional, the historical financial risks and returns of the biotech and pharmaceutical industries, the mechanics of biotech startup financing, capital budgeting for pharmaceutical companies, and applications of financial engineering in drug royalty investment companies, biomedical megafunds, drug approval swaps, and life sciences investment banking.

The target audience for this course includes both Sloan and life-sciences students who are interested in careers in the healthcare industry.

Prerequisite/Corequisite

This course requires that students have either taken or are taking in tandem 15.401 Managerial Finance. This requirement can be waived by permission of instructor.

Class Schedule

The class meets once per week: T 4:00–7:00pm, E62–276. The first half the course will be mainly lectures; classes during the second half of the course will consist of lectures for the first two hours and a guest speaker for the last hour.

Recitations

The TA, Shomesh Chaudhuri, will hold recitations during the first half of the semester on Fridays, 2:00–3:00pm, E51-335. Class material will be reviewed and additional applications and exercises presented. Questions should be directed to shomesh@mit.edu.

Course Website

The primary course website is http://stellar.mit.edu/S/course/15/sp17/15.482/ and all teaching materials except cases and problem sets will be posted on this site, including announcements, TA office hours, lecture notes, readings, handouts, and data. Cases can be downloaded at http://study.net and the online problem sets and case questions, and their solutions, can be found on the MITx website http://bit.ly/2kaElnw.

Office Hours

The course instructor and TA will also hold regular office hours, and the times and locations will be announced on the course website.

Administrative Assistant

Crystal Myler, E62–611, (617) 715–4840, cmyler@mit.edu

Course Requirements and Grading

Course requirements include regular attendance and participation in class which requires having read the assigned articles and/or cases prior to coming to class and being prepared to discuss them (5%), three online problem sets (30%), three online case analyses (30%), and one group project due before the end of the semester (35% = 30% for project deliverables + 5% for peer evaluation). There is no final examination for the class.

The group project involves choosing one of the following options based on the specific interests of your group: (1) prepare a business plan for a biotech startup; (2) perform a financial analysis of a biotech or pharma company as an investment or acquisition target; (3) propose a new funding structure for an unmet medical need, e.g., vaccines for infectious diseases, gene therapies, a clinic for terminally ill patients, healthcare loans for gene therapies, etc.; or (4) a project of your choosing with prior written approval from the instructor (approval must be secured by 14 March 2017). Teams will have the opportunity to present their project to a panel of biopharma experts during the last class, and the most compelling projects will receive awards (presentations are entirely optional and do not affect project grades).

Course Materials

- **Class Notes and Recitation Notes.** Notes will be available on the course website.
- **Research Articles.** Research articles will be made available on the course website.
- **Course Packet.** Case studies for assigned class discussions and assigned readings not available through the MIT Libraries will be made available for purchase on Study.net.

Additional Recommended Readings

S. Mukherjee, *The Emperor of All Maladies*, 2010.

- Pulitzer-prize-winning "biography" of cancer, which is a fascinating introduction to one of the most important motivations for this course.

L. Friedhoff, *New Drugs: An Insider's Guide to the FDA's New Drug Approval Process*, 2009.

- A very concise exposition of the process of getting a drug approved by the FDA, written by an MD/PhD and 30-year veteran of the pharma industry who headed teams that developed and received FDA approval for six new drugs, including the blockbusters Aricept and Aciphex.

Sloan Values

You are responsible for upholding Sloan's code of conduct, which mandates zero tolerance for cheating and plagiarism. For more details on Sloan's academic policies, please read the document "Classroom Values in Practice" which is available on the course website.

Class and Assignments Schedule

Please note that, because this is the first time 15.482 is being offered, the class and assignments schedule is approximate and I reserve the right to make changes depending on the interests and background of the participants.

Class	Topic

L1: 2/7 **Introduction and Financial Analysis for the Life Sciences Professional 1**

- Motivation for healthcare finance
- A taxonomy of the biomedical ecosystem
- Time value of money and present value relations
- Course mechanics

Assigned Readings: Chaudhuri and Lo (2017), Dolan (2011)

R1: 2/10 *Present Value*

L2: 2/14 **Financial Analysis for the Life Sciences Professional 2**

- Inflation, depreciation, and taxes
- Basic accounting relations
- Modeling risk and the risk/reward trade-off
- Portfolio theory

Assigned Readings: Chaudhuri and Lo (2017)
Assigned Problem Set: Present Value Relations

R2: 2/17 *Capital Budgeting and Diversification*

L3: 2/28 **Financial Analysis for the Life Sciences Professional 3**

- The Capital Asset Pricing Model and the cost of capital in biopharma
- The risk/reward characteristics of biotech and pharma
- Option pricing theory and the binomial option pricing formula

Assigned Readings: Chaudhuri and Lo (2017)
Assigned Problem Set: Capital Budgeting and Diversification

R3: 3/3 *CAPM and Options*

L4: 3/7 **Valuation of Life Sciences Assets**

- Applications of derivative securities, credit default swaps, and real options
- Valuing patents, royalties, licensing deals, and milestone payments
- Valuing basic scientific research

Assigned Readings: Chaudhuri and Lo (2017), Feldman (2016), Hatch (2008)
Assigned Problem Set: CAPM and Options

R4: 3/10 *Decision Trees*

Class and Assignments Schedule (continued)

Class	Topic

L5: 3/14 **Developing Therapeutics**

- Introduction to randomized clinical trials and the drug approval process
- Valuing drug development projects as risky cash flows
- Valuing publicly traded biotech and pharma companies
- Guest Speakers: Bob Langer (MIT) and Terry McGuire (Polaris Ventures)

Assigned Readings: Chaudhuri and Lo (2017), Chaudhuri, Ho, Irony, Sheldon, and Lo (2017), Ellimoottil, Vijan, and Flanigan (2015), Isakov, Lo, and Montazerhodjat (2016), Montazerhodjat, Chaudhuri, Sargent, and Lo (2017)

Assigned Case Analysis: Ruback (2003)

R5: 3/17 *Real Options*

L6: 4/4 **Biotech Venture Capital**

- Legal and financial structure of biotech VC funds
- Typical VC deal structures
- How to start a biotech company if you must
- Guest speakers: Neil Kumar and Phil Reilly (BridgeBio Capital)

Assigned Readings: Guo, Lev, and Zhou (2005), Hardymon and Nicholas (2012)

Assigned Case Analysis: Jacquet, Bruner, and Bodily (2014)

L7: 4/11 **Big Pharma**

- The cost of capital, R&D, and pharma capital structure
- Capital budgeting, cash management, and corporate M&A
- Risk management for pharmaceutical companies
- Guest Speakers: Belen Carillo-Rivas (Pfizer), Howard Fingert (Takeda), Bob O'Neill (FDA)

Assigned Readings: Giaccotto, Golec, and Vernon (2011), Hay, Thomas, Craighead, Economides, and Rosenthal (2014), Lynch and Shockley (2016), Paradise (2016), Scannell, Blanckley, Boldon, and Warrington (2012), Wong, Siah, and Lo (2017)

Assigned Case Analysis: Eades, Matos, Aleyev, and Xu (2014)

Class and Assignments Schedule (continued)

Class	Topic

L8: 4/25 **New Biopharma Business Structures**

- SPACs, BDCs, and MLPs; drug royalty investment companies
- Hollywood, project-based organizations, and slate financing
- Venture philanthropy and impact investors
- Guest speakers: Mayukh Sukhatme (Roivant Sciences), Lara Sullivan (Pfizer CURES)

Assigned Readings: Forman, Lo, Shilling, and Sweeney (2015), Higgins and Kazan (2007), Kaplan and Hood (2010), Kim and Lo (2017), Lo (2017), Lo and Pisano (2015), Lo and Naraharisetti (2014), Serafeim, Healy, and Sesia (2011), Siah, Wong, and Lo (2017)

L9: 5/2 **Securitizing Biomedical Innovation and Healthcare Costs**

- Introduction to securitization
- Biomedical megafunds
- Applications in rare diseases, cancer, and infectious diseases
- Guest speakers: John Hull (University of Toronto), Pablo Legorreta (Royalty Pharma), Roger Stein (LFE)

Assigned Readings: Fernandez, Stein, and Lo (2012), Fagnan, Yang, McKew, and Lo (2015), Lo, Ho, Cummings, and Kosik (2015), Montazerhodjat, Frishkopf, and Lo (2016), Hull, Lo, and Stein (2017)

L10: 5/9 **Pricing, Insurance, and Ethics**

- Overview of optimal pricing strategies
- Pharmaceutical pricing policies in the U.S. and abroad
- Ethics of pricing in biopharma, finance, and other industries
- Measuring cost-effectiveness and value-based pricing
- Guest Speakers: Bill Dreitlein (ICER), Cole Gillespie (Lending Club), Brian O'Shea and Mandy Yeung (Genentech)

Assigned Readings: ICER (2015), Caplan, Bateman-House, Waldstreicher (2016), Montazerhodjat, Weinstock, Lo (2016), GAO (2009), GAO (2016), Senate Committee Print (2015), Zaric and Sehgal (2009), Zaric (2010)

L11: 5/16 **Project Presentations**

- Student teams present their projects to the class and an external panel of judges
- Panel of judges: Doug Cole (Flagship Ventures), Christiana Bardon (Burrage Capital), Lita Nelsen (MIT TLO emeritus), Amy Schulman (Polaris Ventures), Vikas Sukhatme (Beth Israel)

Readings

Most readings will be made available on Stellar. Articles with an asterisk must be purchased as part of the course packet on http://study.net

Caplan, A., Bateman-House, A. and Waldstreicher, J. 2016. Compassionate use: A modest proposal," in D. Dizon, ed., ***American Society of Clinical Oncology Educational Book***,. Alexandria, VA: American Society of Clinical Oncology.

Chaudhuri, S., Ho, M., Irony, T., Sheldon, M. and Lo, A. 2017. Patient-centered clinical trials for medical devices. Unpublished pre-print, MIT Laboratory for Financial Engineering.

Chaudhuri, S. and Lo, A. 2017. ***Healthcare Finance: Lecture Notes for 15.482***. Cambridge, MA: MIT Sloan School of Management.

*Dolan, R. 2011. Glaxo and Zantac: The Life, Times, and Near Death of the World's Best-Selling Drug: Teaching Note. Ross School of Business/WDI Teaching Note W90T07.

*Eades, K, Matos, P., Aleyev, D. and C. Xu. 2014. Sanofi-Aventis's Tender Offer for Genzyme. Darden School of Business Case #UV6874.

Ellimoottil, C., Vijan, S. and Flanigan, R. 2015. A primer on clinical trial design. ***Urologic Oncology*** 33, 116–121.

Fagnan, D., Yang, N., McKew, J. and Lo, A. 2015. Financing translation: Analysis of the NCATS rare-diseases portfolio. ***Science Translational Medicine*** 7, 276ps3.

Feldman, R. 2016. The CRISPR revolution: What editing human DNA reveals about the patent system's DNA. ***UCLA Law Review Discourse*** 64, 392–410.

Fernandez, J.-M., Stein, R. and Lo, A. 2012. Commercializing biomedical research through securitization techniques. ***Nature Biotechnology*** 30, 964–975.

Forman, S., Lo, A., Shilling, M. and Sweeney, G. 2015. Funding translational medicine via public markets: The business development company. ***Journal of Investment Management*** 13, 9–32.

Giaccotto, C. , Golec, J. and Vernon, J. 2011. New estimates of the cost of capital for pharmaceutical firms. ***Journal of Corporate Finance*** 17, 526–540.

Guo, R., Lev, B. and Zhou, N. 2005. The valuation of biotech IPOs. ***Journal of Accounting, Auditing and Finance*** 20, 423–459.

*Hardymon, F. and Nicholas, T. 2012. Kleiner-Perkins and Genentech: When Venture Capital Met Sciences. Harvard Business School Case 813-102.

*Hatch, J. 2008. Note on Valuing a Biotech Company. Richard Ivey School of Management, University of Western Ontario, Case #908N05.

Hay, M., Thomas, D. W., Craighead, J. L., Economides, C. and Rosenthal, J. 2014. Clinical development success rates for investigational drugs. ***Nature Biotechnology*** 32, 40–51.

*Higgins, R. and B. Kazan, 2007, Vertex Pharmaceuticals and the Cystic Fibrosis Foundation: Venture Philanthropy Funding for Biotech. Harvard Business School Case 9-808-005.

Hull, J., Lo, A. and Stein, R. 2017. Funding Long Shots, pre-print, MIT Laboratory for Financial Engineering.

ICER. 2015. ***The Comparative Clinical Effectiveness and Value of Novel Combination Therapies for the Treatment of Patients with Genotype 1 Chronic Hepatitis C Infection: A Technology Assessment***, Final Report January 30, 2015.

Isakov, L., Lo, A. and Montazerhodjat, V. 2017. Is the FDA too conservative or too aggressive?: A Bayesian decision analysis of clinical trial design. Forthcoming in ***Journal of Econometrics***.

*Jacquet, P., Bruner, R. and S. Bodily. 2014. Genzyme/GelTex Pharmaceuticals Joint Venture. Darden School of Business Case #UVA-F-1254.

*Kaplan, R. and S. Hood. 2010. Bob Beall at the Cystic Fibrosis Foundation. Harvard Business School Case #9-409-107.

Kim, E. and Lo, A. 2017. Business models to cure rare disease: A case study of Solid Biosciences. ***Journal of Investment Management*** 14, 87-101.

Lo, A. 2017. "Quantifying the Impact of Impact Investing," pre-print, MIT Laboratory for Financial Engineering.

Lo, A., Ho, C., Cummings, J. and Kosik, K. 2014. Parallel discovery of Alzheimer's therapeutics. ***Science Translational Medicine*** 6, 241cm5.

Lo A. and Naraharisetti, S. 2014. New Financing Methods in the Biopharma Industry: A Case Study of Royalty Pharma. ***Journal of Investment Management*** 12, 4–19.

Lo, A. and Pisano, G. 2015. Lessons from Hollywood: A New Approach to Funding R&D. ***MIT Sloan Management Review*** 57.

Lynch, J. and Shockley, R. 2016. Valuation of a developmental drug as a real option. ***Journal of Applied Corporate Finance*** 28, 118–126.

Montazerhodjat, V., Chaudhuri, S., Sargent, D. and Lo, A. 2017. Patient-centered randomized clinical trials in oncology via Bayesian decision analysis. Forthcoming in ***JAMA Oncology***.

Montazerhodjat, V., Frishkopf, J. and Lo, A. 2016. Financing drug discovery via dynamic leverage. ***Drug Discovery Today*** 21, 410–414.

Montazerhodjat, V., Weinstock, D. and Lo, A. 2016. Buying cures vs. renting health: Financing healthcare via consumer loans. ***Science Translational Medicine*** 8, 327ps6.

Paradise, J. 2016. A profile of bio-pharma consolidation activity. ***Annals of Health Law*** 25, 34–61.

*Ruback, R. 2003. Merck & Company: Evaluating a Drug Licensing Opportunity. Harvard Busines School Case #9-201-023.

Scannell, J., Blanckley, A., Boldon, H. and Warrington, B. 2012. Diagnosing the decline in pharmaceutical R&D efficiency. ***Nature Reviews Drug Discovery*** 11, 191–200.

Senate Committee Print. 2015. ***The Price of Sovaldi and its Impact on the U.S. Health Care System***, 114–20. Washington, DC: U.S. Government Publishing Office.

*Serafeim, G., Healy, P. and Sesia, A. 2011. *Oddo Securities – ESG Integration*. HBS Case #111085-PDF-ENG.

Siah, K., Wong, C. and Lo, A. 2017. Machine-learning models for predicting drug approvals and clinical-phase transitions. Preprint, MIT Laboratory for Financial Engineering.

U.S. Government Accountability Office (GAO). 2009. ***Brand-Name Prescription Drug Pricing***. Washington, DC: U.S. Government Publishing Office. http://www.gao.gov/new.items/d10201.pdf

U.S. Government Accountability Office (GAO). 2016. ***Generic Drugs Under Medicare***. Washington, DC: U.S. Government Publishing Office. http://www.gao.gov/products/GAO-16-706

Wong, C., Siah, K. and Lo, A. 2017. Estimation of clinical trial success rates and related parameters. Preprint, MIT Laboratory for Financial Engineering.

*Zaric, G. and Sehgal, C. 2009. The Challenge of Access to Oncology Drugs in Canada. Richard Ivey School of Business, University of Western Ontario, Case #909E2.

*Zaric, G. 2010. Difficult Choices—An Introduction to Cost Effectiveness Analysis. Richard Ivey School of Business, University of Western Ontario. Case #910E07.