WHAT IS CHEMICAL ENGINEERING

Chemical engineers have made so many important contributions to society that it is hard to visualize modern life without the large-volume production of antibiotics, fertilizers and agricultural chemicals, special polymers for biomedical devices, high-strength polymer composites, and synthetic fibers and fabrics. How would our industries function without environmental control technologies; without processes to make semiconductors, magnetic disks and tapes, and optical information storage devices; without modern petroleum processing? All these technologies require the ability to produce specially designed chemicals economically and with a minimal adverse impact on the environment. Developing this ability and implementing it on a practical scale is what chemical engineering is all about.

化学工程师们为社会做出了如此多的贡献以致很难想象现代生活中没有大规模生的产抗生素，化肥，农用化学品，特种高分子生物医学装置，高强度高分子复合材料，合成纤维和织物。没有环境控制技术我们的工业会怎样运作；没有半导体，磁碟和磁带，光学存储装置，没有现代炼油工厂我们的生活将会怎样。

Every scientific discipline has its characteristic set of problems and systematic methods for obtaining their solution - that is, its paradigm. Chemical engineering is no exception. Since its birth in the last century, its fundamental model has undergone a series of dramatic changes.

每一个科学领域都有它独有的一组命题，以及获取其答案的系统方法，这就是范式。化学工程也不例外。从它自上世纪诞生起，它的基本模式经历了一系列的戏剧性变化。

TRADITIONAL PARADIGMS OF CHEMICAL ENGINEERING

化学工程的传统范式

When the Massachusetts Institute of Technology (MIT) started a chemical engineering program in 1888 as an option in its chemistry department, the curriculum largely described industrial operations and was organized by specific products. The lack of a paradigm soon became apparent. A better intellectual foundation was required because knowledge from one chemical industry was often different in detail from knowledge from

other industries.
1888 年，当麻省理工学院在其化学系中开设化学工程选修方向时，它的课程设置主要描述工业运营，且主要按照特定产品组织规划。缺乏一种范式很快就显现出来了。化学工程需要一个更好的学术基础，因为从业界来的知识，其具体内容常常随化工行业的不同而不同。

The first paradigm for the discipline was based on the unifying concept of "unit operation" proposed by Arthur D. Little in 1915. It evolved in response to the need for economic large-scale manufacture of commodity products. The concept of unit operation held that any chemical manufacturing process could be resolved into a coordinated series of operations such as pulverizing, drying, roasting, crystallizing, filtering, evaporating, distilling, electrolyzing, and so on. Thus, for example, the academic study of the specific aspects of turpentine manufacture could be replaced by the generic study of distillation, a process common to many other industries.
学科的第一个范式是基于统一“单元操作”这一概念，由 Arthur D. Little 于 1915 年提出的。它是响应经济地大规模生产大宗产品的需要的演化结果。单元操作的概念认定任何化工制造过程可以被拆解成关联的系列操作，例如粉碎，干燥，焙烧，晶化，过滤，蒸发，蒸馏，电解，等等。因此，例如，松节油生产中某个特定问题的学术研究，可以用更通用的、在很多其它行业中共有的精馏过程的研究来替代。

During the period of intensive development of unit operations, other classical tools of chemical engineering analysis were introduced or were extensively developed. These included studies of the material and energy balance of processes and fundamental thermodynamic studies of multicomponent systems.
在密集开发单元操着的期间，化学工程分析中另一些经典工具也被引入或者被广泛地建立。这些包括了过程中物质和能力守恒的研究以及多组分系统基础热力学的研究。

Chemical engineers played a key role in helping the United States and its allies win World War II. They developed routes to synthetic rubber to replace the sources of natural rubber. They provided the uranium-235 needed to build the atomic bomb. And they were instrumental in perfecting the manufacture of penicillin, which saved the lives of hundreds of thousands of wounded soldiers.

化学工程师们在帮助美国及其盟国赢得第二次世界大战中起到了关键作用。他们开发了合成橡胶的方法用于取代天然橡胶资源。他们提供了用于制造原子弹的铀-235。并且他们帮助最优化青霉素的制造，挽救了成百上千的伤员。

The high noon of American dominance in chemical manufacturing after World War II saw the gradual exhaustion of research problems in conventional unit operations. This led to the rise of a second paradigm for chemical engineering, pioneered by the engineering science movement. Dissatisfied with empirical descriptions of process equipment performance, chemical engineers began to reexamine unit operations from a more fundamental point of view. The phenomena that take place in unit operations were resolved into sets of molecular events. Quantitative mechanistic models for these events were developed and used to analyze existing equipment, as well as to design new process equipment. Mathematical models of processes and reactors were developed and applied to capital-intensive industries such as commodity petrochemicals.

二次世界大战后，正值美国在化工产业统治地位的正午期，人们发现传统单元操作研究命题逐渐枯竭。这导致了由工程科学运动为先锋的化学工程第二个范式的兴起。不在满足于以往对过程设备性能的经验性描述，化学工程师们开始从更基础的观点重新检验单元操作。通过对一组分子所发生的事件的描述来解释单元操作中所发生的现象。而为这些事件所开发出的定量的、机理性的模型被用来分析现有的设备以及设计新的过程设备。开发出来的过程和反应器的数学模型被用于高资本投入的行业，例如生产大宗商品的石油化工工业。

THE CONTEMPORARY TRAINING OF CHEMICAL ENGINEERING

现代化工教育

Parallel to the growth of the engineering science movement was the evolution of the core chemical engineering curriculum in its present form. Perhaps more than any other development, the core curriculum is responsible for the confidence with which chemical engineers integrate knowledge from many disciplines in the solution of complex problems.

伴随着工程科学运动的成长，化学工程的核心课程出现了演变，并以现在形式存在。或许，比较起其它方面的发展，核心课程更应该被认为是化学工程师们能够整合众多学科为复杂命题提供答案的原因。

The core curriculum provides a background in some of the basic sciences, including mathematics, physics, and chemistry. This background is needed to undertake a rigorous study of the topics central to chemical engineering, including: multicomponent thermodynamics and kinetics, transport phenomena, unit operations, reaction engineering, process design and control, and plant design and system engineering.
核心课程提供了一些基础科学背景知识，包括数学，物理和化学。这些背景知识是对化学工程核心课题进行精准研究所必须的，包括：多组分热力学和动力学，传递现象，单元操作，反应工程，过程设计与控制，和工厂设计与系统工程。

This training has enabled chemical engineers to become leading contributors to a number of interdisciplinary areas, including catalysis, colloid science and technology, combustion, electrochemical engineering, and polymer science and technology. Because chemical engineering is the most broadly based of all engineering disciplines, the chemical engineer is in great demand in diverse technical and supervisory areas in a wide variety of industries, and has consistently commanded one of the highest starting salaries of all college graduates.
这一训练使得化学工程师们能够成为众多交叉领域，包括催化，胶体科学和技术，燃烧，电化学工程，和高分子科学和技术的最重要的贡献者。因为化学工程是基础最宽泛的工程学科，化学工程师在不同行业中的众多技术和管理领域中有巨大的需求，并且始终占据着所有大学学科中起薪最高者的位置。

A NEW PARADIGM FOR CHEMICAL ENGINEERING

新的化学工程范式

Over the next few years, a confluence of intellectual advances, technological challenges, and economic driving forces will shape a new model of what chemical engineering is and what chemical engineers do.
在接下来的几年里，学术进步，技术挑战，和经济推动力将汇流在一起，形成化学工程和化学工程师将发挥作用的新模式。

A major force behind this evolution will be the explosion of new products and materials that will enter the market during the next two decades. Whether from the biotechnology industry, the electronics industry, or the high-performance materials industry, the products will be critically dependent on structure and design at the molecular level for their usefulness. They will require manufacturing processes that can precisely control their chemical composition and structure. These demands will create new opportunities for chemical engineers, both in product design and in process innovation.

在这个演变背后的主要推力将是在接下来的二十年里，爆发式出现的新产品和新材料将进入市场。无论是从生物技术行业，电子行业，或高性能材料行业，这些产品的可用性至关重要地取决于其在分子层面的结构和设计

A second force that will contribute to a new chemical engineering paradigm is the increased competition for worldwide markets. Product quality and performance are becoming more important to global competition than ever before. The key to meeting these challenges is innovation in process design, control, and manufacturing operations.

新化学工程范式的第二个推动力将是在世界范围内与日俱增的竞争。产品的质量和性能将在全球竞争中比以往更重要。迎接这些挑战的关键在于过程设计，控制和生产运营的创新。

The third force shaping the future of chemical engineering is society's increasing awareness of health risks and environmental impacts from the manufacture, transportation, use, and ultimate disposal of chemicals. This will be an important source of new challenges to chemical engineers.

未来的化学工程的第三种推动力将是社会对健康风险和化工产品的生产，运输，使用，和废弃对环境冲击的日益觉醒。

The fourth and most important force in the development of tomorrow's chemical engineering is the intellectual curiosity of chemical engineers themselves. As they extend the limits of past concepts and ideas, chemical engineering researchers are creating new knowledge and tools that will profoundly influence the training and practice of the next generation of chemical engineers.

明日化学工程发展的第四种也是最重要的推动力是化学工程师们自身的学术好奇心。在将以往的概念和观念的极限向前拓展的同时，化学工程的研究者们正在创立新的知识和工具，这些新知识和工具将对他们自身的训练与实践产生深远的影响。

When a discipline adopts a new paradigm, exciting things happen, and the current era is probably one of the most challenges and potentially rewarding times to be entering chemical engineering. Future chemical engineers will bring new tools and insights to research and practice from other disciplines: molecular biology, chemistry, solid-state physics, material science, and electrical engineering. And they will make increasing use of computers, artificial intelligence, and expert systems in problem solving, in product and process design, and in manufacturing.

当一种学科接受新的范式的时候，令人兴奋的事情往往发生，而现在，对于进入化学工程领域的人来说，或许是有史以来最具挑战并且最有回报潜力的时代，

Some things, though, will not change. The underlying philosophy of how to train chemical engineers - emphasizing basic principles that are relatively immune to change in field of application - must remain constant if chemical engineers of the future are to master the broad spectrum of problems that they will encounter.

当然，有些事是自古不变的。如果未来的化学工程师们想要能够主宰他们将会遇到的范围广泛的问题，如何训练一名化学工程师的内在哲学—强调相对独立于应用领域变化的基本原理—必须保持稳定。