Understanding Bistability in Complex Enzyme-Driven Reaction Networks

Lecture 2

The machinery of the cell consists, in large part, of a bewildering collection of distinct biochemical reactions mediated by the action of enzymes. Kinetic functions that describe the dependence of individual reaction rates on mixture composition are rarely known with great precision (if they are known at all), and so the most apt questions are often qualitative ones. In particular, one would like to know the relationship between the structure of a biochemical reaction network and its qualitative capacity to exhibit various kinds of dynamical behavior. Our special interest will be in capacity of complex enzyme-driven reaction networks to admit bistability—that is, the capacity of the corresponding differential equations to admit two (or more) distinct stable stationary states. It turns out that some rather simple classical mechanisms for enzyme catalysis already carry the capacity for bistable behavior while other large and complex enzymatic networks do not. Indeed, the connection between network structure and the capacity for bistability is surprisingly delicate. Thus, a good theory of such connections must be capable of dealing with reasonably large reaction networks and yet be subtle enough to draw dramatic behavioral distinctions between networks that are very similar. We’ll describe some recent work with Chorlge Craciun that takes us a good way down the road toward resolution of the problem. In particular, we’ll consider the capacity for bistable behavior in a network underlying the action of a particular enzyme, one that is a target of classical anti-cancer therapies.

Professor Amundson is recognized as an exceptionally prolific, innovative and influential researcher. His contributions include modeling and analysis of chemical reactors, separation systems, polymerization, and coal combustion. He had a profound, pioneering impact on the education of chemical engineers, changing the teaching of the field from a qualitative, descriptive approach to precise scientific methodology.

Professor Amundson was the first to incorporate advanced mathematics into chemical engineering research and chemical engineering undergraduate and graduate education. He was the first to apply the principles of non-linear mechanics to lumped constant chemical reactor systems, enabling him to explain chemical reactor instability, oscillatory behavior, and parametric sensitivity. Amundson developed the complete theory of multi-component column chromatography, including shock interactions, which led to the determination of the underground movement of pollutants. He applied modern mathematics to multi-component and continuous distribution of component rectification and developed complete solutions.

The field of chemical reactor engineering, as well as the concept of reaction coupled with diffusion, was also first developed by Professor Amundson. With the threat of the essential use of coal, Professor Amundson initiated a systematic and exhaustive development of the gasification of coal char, the products of which would have been used in fuel synthesis. He also constructed a physical and mathematical model and participated in the systematic design of the first nuclear submarine, the Nautilus.

A native of St. Paul, Minnesota, Neal R. Amundson received a bachelor of science degree in chemical engineering, a master’s degree in chemical engineering and a doctorate in mathematics from the University of Minnesota. Professor Amundson remained at the University of Minnesota, teaching both chemical engineering and mathematics. In 1949 he became head of the Department of Chemical Engineering, and he continued as department head for the next 25 years. Professor Amundson joined the University of Houston’s Department of Chemical Engineering in 1977, and he also served as University Provost from 1987 to 1989. He is currently an active researcher and mentor in the Department of Mathematics at the University of Houston.