# 1 No-Boundary Thinking

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What is No-Boundary Thinking (NBT)? Is it a philosophy term or a science term? Why do we need it? Since 2013, the NBT national network has had many discussions and today wants to have a book to include some of the NBT group members' thoughts. Some may affect NBT, some may not. Still, we would like to put it all together.

What is NBT? No-Boundary Thinking is no-boundary problem defining on time chain to address real science challenges. This is the definition for now, and for many future years in science. No-Boundary Thinking is still No-Boundary Thinking, even with subtraction and more subtraction. Even with addition and more addition, multidisciplinary research is still multidisciplinary. It is different from multidisciplinary, interdisciplinary, or transdisciplinary research. It is also different from the *convergence* approach currently promoted by the National Science Foundation (NSF). No-Boundary Thinking is like the sea: sometimes the sea is rising, sometimes the sea is retiring; it is still the complex sea.

Current NSF/NIH (National Institutes of Health) projects are like collecting water in many confined pools, and even convergence aims to connect these pools into big pools. Of course, they make some contributions to science. However, they are not like running rivers. Running rivers could be big or small, but they lead to the sea, and are eventually parts of the sea.

Today we see the rapid development of science and technology, and the great accumulation of knowledge and wealth. We have powerful machines, high-performance computers, and broadband Internet. We see more and more data being generated, collected, and distributed, and we see new interdisciplinary areas of science appearing and expanding rapidly. Recently we have seen the surge of artificial



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intelligence, with big data and powerful computers, which is changing the frontiers of science research and industrial innovation. People are expecting new heights in science, a new paradigm.

We know there were big jumps in science and technology throughout human history, with great impacts. Five hundred years ago the Renaissance brought us Da Vinci and Michelangelo, and the new thinking of humanism, which stimulated the development of all areas, including art, science, architecture, politics, and literature. Two hundred years ago the Industrial Revolution brought us Watt, Fulton, and Stephenson, and new machines tools, factory systems, population growth, and wealth accumulation that changed everyday life.

Today, people are proclaiming a new paradigm is coming: the big data paradigm. Data-intensive computing (big data) was advocated as the fourth paradigm for scientific discovery (Hey et al. 2009). In recent years researchers, funding agencies, and companies have promoted data science research. The federal funding agencies – the NSF and NIH – have made large investments in big data and related programs, such as NIH BD2K and NSF BIGDATA. Recently the NSF has identified one of its 10 big ideas, *convergence*, as "a means of solving vexing research problems" and described it as "the closest to transdisciplinary research" (NSF n.d.).

But, we wonder: Can big data, data science, transdisciplinarity, or convergence really bring us what we expect – a new age in science, a new paradigm? Powerful machines drove the Industrial Revolution; can big data similarly drive the current rise of science?

Since 2013 we have been discussing, as a national network, how to address real science challenges and the limitations of big data and interdisciplinary research. We have discussed the future development of bioinformatics and the issues of big data (Huang et al. 2013, 2015; Moore et al. 2017). Big data seems unable to address science challenges the way it promises to, such as the Human Genome Project and The Cancer Genome Atlas (TCGA) project.

In our previous paper (Huang et al. 2015) we discussed the TCGA initiative as an example:

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> For the pilot project and phase II of TCGA, about US$200-million has been invested in this effort to gather samples, generate data, and analyze the data. The Cancer Genome Atlas (TCGA), may have produced some good results published in Nature and Science, but the approach of big data overall is disconnecting researchers and science challenges. Efforts like TCGA are reaching the "bottleneck;" it is hard to make significant breakthroughs in scientific challenges by focusing on big data and over-simplified problems.

Two years ago I asked one of my collaborators, who worked in the research area of cancer genomics for 30 years and recently retired: Given another 30 years, would you design your research the same way? He directly answered: No.

Current funding agencies, including the NSF and NIH, in a way encourage researchers to focus on oversimplified problems that can be solved or for which results can be generated in a funding period of 3–5 years. However, for many real science challenges we know we may not be able to resolve them in our lifetimes. When we explore science challenges and conduct research design we may consider leaving a window for the next generation to conduct research.

A senior scientist once asked me: Multidisciplinary, interdisciplinary, or transdisciplinary research seems ineffective and cannot address real science challenges – how about "very" interdisciplinary? I asked: But how "very" is enough?

We promote NBT. The intellectual basis of the Renaissance was humanism, where "Man is the measure of all things." No-Boundary Thinking is a science renaissance, where "human intelligence" with NBT is the measure of science.

No-Boundary Thinking is no-boundary problem defining. One intelligent young scientist said his senior advisor told him: "Do not continue to stay in this house to try to do further carving and decorating, or try to add more refined adds-on to the house anymore; too many people have worked on this house. You should leave and go to

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build a new house." We would suggest to answer: "I am not going to leave, because I want this land. I want to tear down to remove the house here and build a new house here, indeed, a new mansion on this land." This piece of land is the real science challenge; a restructured mansion is the redefined problem, with the problem solution incorporated into the problem definition.

Why time chain? The time chain is a new concept; it is related to the process of problem defining and redefining. It is no-boundary problem defining and redefining. The new mansion may not be as refined as the previous house at the beginning, but its structure is clear and different, and it has the ability to self-recycle and even to self-restructure. As time passes on the time chain, the mansion may all be cleared up one day, and this piece of clear land may be connected with other lands to build a new structure. No-Boundary Thinking, with the land and the time chain, is high-dimensional. NBT is the pursuit of no-boundary thinking in science and in science history.

The purpose of this book is not to present NBT research results or education outcomes, but to stimulate more thought regarding NBT in science, research, and education.

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