

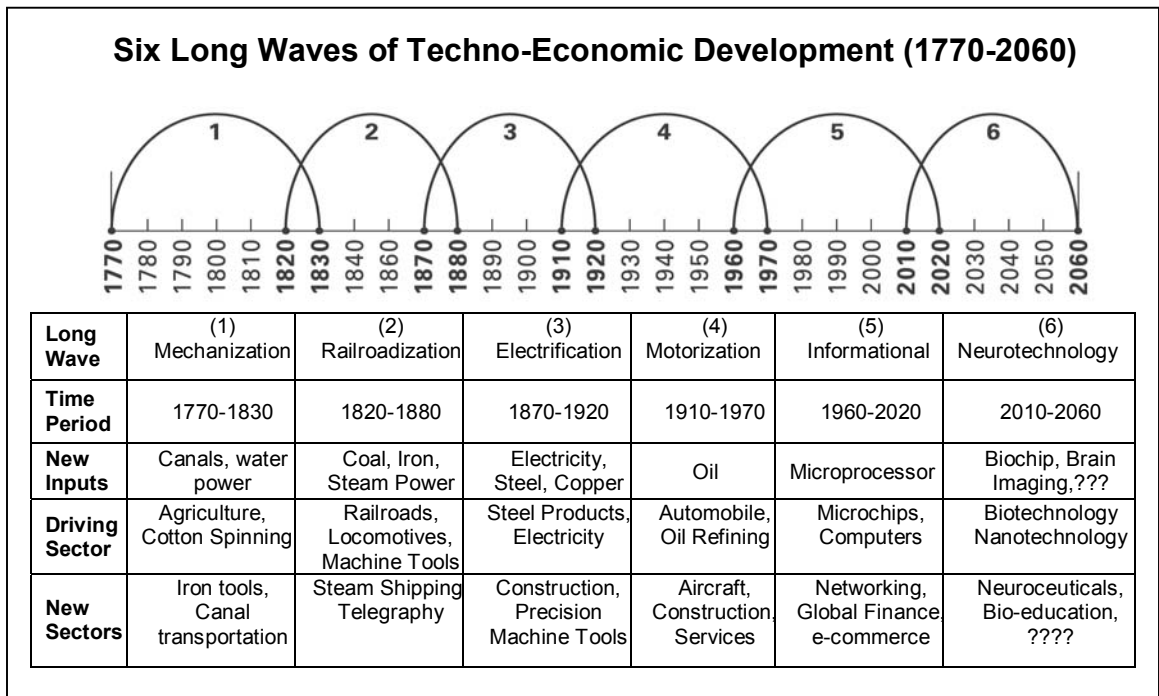
Neurotechnology and Society (2010-2060)

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Society shapes and is shaped by advancing technology. To illuminate the important societal implications of the NBIC (*nano-bio-info-cogno*) convergence it is critical to place it within a broad historical context. History focuses the issues that are cloudy and require attention versus the ones that have more certain trajectories. By viewing history as a series of techno-economic waves with accompanying socio-political responses it is possible to begin to understand how NBIC technologies will impact society.

Since the industrial revolution there has been a relatively consistent pattern of 50-year waves of techno-economic change. We are currently nearing the end of the fifth wave of information technology diffusion, while a sixth wave is emerging with converging advancements across the NBIC (*nano-bio-info-cogno*) space. The sixth wave is neurotechnology and revolves around enhancing human performance.

Each wave consists of a new group of technologies that make it possible to solve problems once thought intractable. The water mechanization wave (1770-1830) in England transformed productivity by replacing handcrafted production with water-powered “machine-o-facture.” The second wave (1820-1880), powered by a massive iron railroad build-out, accelerated the distribution of goods and services to distant markets. The electrification wave (1870-1920) produced inexpensive steel, thereby transforming the railroad systems again, while also providing the foundation for the modern city. The development of skyscrapers, electric lifts, light bulbs, telephones and subways were all a result of the new electricity infrastructure. The fourth wave (1910-1970) ushered in mass assembly and the motorization of the industrial economy, making the inexpensive transportation of goods and services available to the masses.



The most recent wave, the information technology wave (1960-2020), has made it possible to collect, analyze and disseminate data, transforming our ability to track and respond to an ever

changing world. Driven by the microprocessors capacity to compute and communicate data at increasingly exponential rates, the current wave is the primary generator of economic and social change today.

The nascent neurotechnology wave (2010-2060) is being accelerated by the development of biochips and brain imaging technologies that make biological analysis inexpensive and pervasive. Biochips that can perform the basic bio-analysis functions (genomic, proteomic, biosimulation, and microfluidics) at a low cost will transform biological analysis and production in a very similar fashion as the microprocessor did for data. Nano-imaging techniques will also play a vital role in making the analysis of neuro-molecular level events possible. When data from advanced biochips and brain imaging are combined they will accelerate the development of neurotechnology, the set of tools that can influence the human central nervous system, especially the brain. Neurotechnology will be used for therapeutic ends and to enhance human emotional, cognitive and sensory system performance.

Techno-economic waves have pervasive effects throughout the economy and society. New low-cost inputs create new product sectors. They shift competitive behavior across the economy, as older sectors reinterpret how they create value. New low cost inputs become *driving sectors* in their own right (e.g. canals, coal, electricity, oil, microchips, *biochips*). When combined with complementary technologies, each new low cost input stimulates the development of *new sectors* (e.g. cotton textiles, railroads, electric products, automobiles, computers, *bio-education*). Technological waves, because they embody a major jump up in productivity, open up an unusually wide range of investment and profit opportunities, leading to sustained rates of economic growth.

The diffusion of the neurotechnology wave will lead to a restructuring of major portions of the economy. Individuals and organizations will respond by creating new:

- *Product mixes that take advantage of advanced biochips and brain imaging.* For example, neuroceuticals that are based on information about an individual's genetic and neural organization will make it possible to influence and enhance human emotional, cognitive and sensory capabilities.
- *Forms of competitive advantage.* For example, innovation is a complex mental function wherein cognitive assessment and emotional compassion combine to accelerate the creation of new knowledge. Individuals that utilize neuroceuticals to become more productive and creative will attain biocompetitive advantage.
- *Patterns in the location of production.* For example, India and China will contain regional clusters of neurotechnology firms as political and cultural views on human testing create the necessary conditions for technological experimentation and development
- *Infrastructures through significant capital investment.* Infrastructures include both tangible infrastructures for their manufacture and distribution and intangible infrastructures, in the form of education and training systems, prevailing management styles, and legal and political frameworks at the regional, national, and global levels.

By viewing recent history as a series of techno-economic waves ushered in by a new low cost input, we can see that sustained investment in the NBIC technologies will lead to substantial economic, political and social change. Neurotechnology has the potential to create new industries, reinvigorate others, develop new forms of social and political organization, and make possible different modes of artistic expression. In its wake neurotechnology will give rise to a new type of human society, a neurosociety.