Twenty-Five Centuries of Technological Change **G. Hyland**
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Prof. Joel Mokyr (PhD Yale, 1974) is an economic historian at NorthWestern University, Illinois USA, and a Professorial Fellow at the University of Tel Aviv. A former chair of the Economics Department and President of the Economic History Association, he is a member of the American Academy of Arts and Sciences, and present editor-in-chief of the book series "The Princeton University Press Economic History of the Western World".

Six basic chapters with a comprehensive bibliography address technology's evolution from classical times to the early 20th Century. Each is well referenced with foot notes backed-up by primary and secondary references, e.g. the Antipater of Thessalonika, "The Development of Iron and Steel Technology in China" Needham J. Cambridge University Press 1964, "The Mechanization of Reaping and Mowing in American Agriculture, 1833-1870" Journal of Economic History. Chapters walk through 1) Classical Antiquity, 2) the Middle Ages, 3) the Renaissance, 4) the Industrial Revolution, 5) the Later Nineteenth Century and finally 6) a Retrospective on technology's roots.

An incomplete skim – In the Classical World progress focused on civil and hydraulic engineering and architecture. Solutions to fresh water supply, drainage, sewage and garbage disposal centered on the Roman discovery of *pozzolana* cement masonry. The Middle Ages saw Islamic and Oriental influence, e.g. chemicals came from both. The West absorbed and pulled ahead (1200-1500), e.g. ships could sail 50-60 degrees off-wind with a lateen sail steered by a Chinese rudder, but "The Invention" was the *carrack* tri-mast vessel by adding fore-&-mizzenmasts. The agricultural revolution was spurred by creation of the three field crop rotation system and the *carruca* (heavy plow) powered by nailed horseshoe and the modern horse-collar (efficiency 5X up). Whilst the windmill combined ideas of water & sail, widespread application of the waterwheel combined with cams and crankshafts fueled energy provision. The printing press disseminated knowledge producing more books in 50yrs than the previous thousand. "The key machine of the industrial age" was the weight driven mechanical clock. 17th Century Renaissance science was "experimental philosophy" with the application of mathematics (decimal point, logarithms), algebra (India), and birth of accounting (double-entry book-keeping). Creating intellectual property rights (IPR) helped, Guilds impeded. The rise of nation states lead to industrialization initiatives, e.g. Russia & Sweden imported foreign specialists to catch-up. "New Husbandry" came; stall feeding of cattle, new crops (corn, potatoes & tobacco) & fallowing, iron ploughs with curved mould-boards and seed-drills. Cod line-fishing and salting of herring increased protein output. Shipping; separate topmast, Dutch shipbuilding yards and specialized vessels, e.g. the Dutch *fluyt* undercut British shipping 30-50%. It was "the age of the pump" – improvements in mining, ventilation and drainage (patents!). Increasing systematic investigation and training was the hallmark of the Later Nineteenth Century, the age of steel and chemicals. The Bessemer converter and Siemens-Martin open-hearth process revolutionized production of cheap steel. Dye manufacturing (German dominated) lead to the chemical industry (explosives, fertilizers, rubber, plastics, oil refining). Faraday's motor and dynamo made possible electricity. Transport advances centered on the expansion of the railroads, the bicycle, and the internal combustion engine (car). The most important development was the "American" system (first applied to guns) of manufacturing assembled complex products from mass-produced individual interchangeable components. Continuous-flow production followed, leading to assembly lines.

The journey, neither linear nor unidirectional, has been economically efficient. Most advances occurred in Europe where centers-of-gravity tended to be short lived, and spurts of technological creativity (imitation and innovation) interspersed fallow times. Inventions are either evolutionary (micro) or disruptive revolutionary (macro). Non-scientific taproots include serendipity, luck & inspiration. The growth mechanism is Schumpeterian (quasi-monopoly), Solovian (capital deepening), Smithian (commercial expansion) and scale effects (one shudders to recall Malthus here). It's impossible to distinguish associativity and causality – worthy of note to the IPR crowd. Possible room for improvement – include the Modern Era (last hundred years), where we appear to be going (with the Knowledge Economy) and perhaps an in-depth analysis on the effects and role of IPR on all this.

Overall – if you ever wondered "we are where we are, but how did we get here?" then read this spellbinding *safari*.