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VERS LA MACHINE À GOUVERNER

Herbert Simon and the Impossibility of a Democratic Computer

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As a commitment to free software, this text was composed in GNU Emacs, typeset in 12 pt. Linux Libertine with LaTeX 2_ε and KOMA-Script, and compiled in LuaTeX.

Contents

ACKNOWLEDGEMENTS iii

NOTE AUX LECTEURS FRANCOPHONES v

PREFACE vii

1 THOUGHTS 1

2 INTRODUCTION 3
- 2.1 Automation, AI and the Future of Work 3
- 2.2 Outline of the Thesis 4

3 TRIFLING PINS *&* UNTUTORED CALCULATORS 7
- 3.1 Introduction 7
- 3.2 Prony background 8
- 3.3 Bureau du cadastre background 8
- 3.4 Technical description 9
- 3.5 Conclusion 12

4 MECHANIZING THOUGHT 13
- 4.1 Introduction 13
- 4.2 Babbage's Engines 14
- 4.3 The Cogwheel Brain 17
- 4.4 Conclusion 19

5 CONCLUSION 21

CONCLUSION 23

Abbreviations

ARCHIVAL SOURCES

When citing archival materials, I indicate their location within the following archives:

HSCM: Herbert Simon Papers, Carnegie Mellon University Archives.

ENPC : École nationale des ponts et chaussées.

BNF : Bibliothèque nationale de France.

I accessed them through their respective on-line repositories.

HSCM: Carnegie Mellon University Libraries Digital Collections.

ENPC : Bibliothèque numérique patrimoniale des ponts et chaussées.

BNF : Gallica.

Only the pdf version of this document includes hyperlinks to the source files, when available.

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Carlos Alberto Rivera Carreño
April 22, 2019
Bagneux, France

Note aux lecteurs francophones

Le fait que ce mémoire fut préparé au sein d'une université française m'oblige moralement à …aux lecteurs francophones.

Ce mémoire traite de la relation entre l'histoire du concept de travail, l'histoire de l'orinateur, l'histoire de l'intelligence, et la pensée de Herbert Simon. J'essai de replacer l'histoire de travail au sein des questions sur l'application des analogies entre les sciences sociales et les sciences naturelles.

Dans le premier chapitre je raconte …

Dans le deuxième chapitre je raconte …

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Preface:
Science and History

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1

Thoughts

I want to advance certain ideas regarding the consequences of automation on work and employment from the perspective of historical epistemology.

Aristotle, who had justified slavery on the seeming impossibility of instruments operating themselves,[1] would have been baffled by current fears that artificial intelligence wipe out thousands of jobs.

The fear of human redundancy is not new.

in the 19th century, Sismondi was outraged at the possibility that "the King, alone in an island constantly turning a handle, carry out with automatons all the work of England." **sismondi1819_2**.

From a cursory view of how

My point of view is that many of the various analysis on this matter are marred by their narrow scope that only focuses on the possible impact of new technologies on what economista call macroeconomic varibales. Briefly put, the videws of neocalssical or mainstream economists, whether optimists or pessimists are decided on whatever the economist thinkgs that the impact of these technologies will be on macroeconomic variables such as investment, consumption, employments, wages, etc.

1. "For if each instrument could perform its own function on command or by anticipating instructions, and if–like the statues of Daedalus or the tripods of Hephaestus (which the poet describes as having "entered the assembly of the gods of their own accord")—shuttles wove cloth by themselves, and plectra played the lyre, an architectonic craftsman would not need assistants and masters would not need slaves." (Politics, 15).

2

Introduction

Sunday night September 23, 1962, the *The Jetsons*, an animated sitcom, aired for the first time, introducing audiences across the United States to the futuristic life of the Jetson family. Just like *The Flintstones* had done for the Stone Age, William Hanna and Joseph Barbera celebrated the American way of life in a future of private flying cars, nuclear family arrangements, and–oddly enough–salary work. George Jetson, the proverbial American *everyman*, , while his wife Jane Jetson, relieved from the drudgery of house chores thanks to the robot maid and automated apartment, is nonetheless relegated to the house. It is quite strange to think that in this future, despite all the automation, neither George nor Jane are free from work. In fact, they still have vacations in their future, something one would think irrelevant in a time of leisure.

The problem with the Jetsons is that the horrible message it depicts: the only change in the future is technical change but not political nor social. The *apories* of this conception of the possibilities of the future only in terms of technical possibilities is, however problematic.

2.1 AUTOMATION, AI AND THE FUTURE OF WORK

That said, fears of human redundancy are not new, since already in the 19^{th} Sismondi was preoccupied at the unemployment caused by the greater productivity of automatic machinery, he was outraged at the possibility that "the King, alone in an island constantly turning a handle, carry out with automatons all the work of England." **sismondi1819_2**.

Since the last years of the 20^{th} century, advances in AI, from the defeat of then World Chess Champion Garry Kasparov by IBM's Deep Blue computer in 1997 to the recent advances in self-driving cars, fears of human redundancy in an age of more powerful and intelligent computers have been up for over two decades, especially since the publishing of the famous Jeremy Rifkin's book **rifkin1996**.

On November 14, 1957, in an address to the Twelfth National Meeting of the Operations Research Society of America, Herbert Simon advanced the provocative proposition that "physicists and electrical engineers had little to do with the invention of the digital computer", for "the real inventor was the economist Adam Smith, whose idea was translated into hardware through successive stage of development by two mathematicians, Prony and Babbage." **simon_newell1958**.

2.2 OUTLINE OF THE THESIS

This thesis is invitation to think the challenges of automation and artificial intelligence from the point of view of the epistemology of labor. To do so, this thesis will present a historical epistemology of the relation between de Prony's project of the calculation of the logarithmic tables at the *Bureau du cadastre*, Babbage's calculating Engines, and the ideas at the time about of labor.

The first chapter discusses the relation between Adam Smith's concept of the division of labor and Gaspard de Prony's project of the calculation of the logarithmic tables. This story will be contextualized for it took place at a time of great changes in French society. What will be emphasized is that this vast computing project was, above all, the reflect of a particular organization of *mental* work. The idea is to provide an understanding of the significance of the project at the time, and the subsequent significance that it had for Charles Babbage.

The introduction to this chapter presents the reader with the story of how Gaspard-Clair-François-Marie Riche de Prony was inspired by Adam Smith's concept of the division of labor–as it appears in the pin factory example of the "Wealth of Nations"—to organize a group of hairdressers to produce mathematical tables for the French *Bureau du cadastre*, during the aftermath of the French Revolution. The point is to show that the "computer" is in fact an organization of labor, in which complex calculation tasks are divided into simpler calculation tasks, which are then carried out by unqualified "specialized" workers (or in computer science lingo, by *sub-processes*).

In the second chapter, I will discuss the interpretation of the importance of this project by Charles Babbage. I will show that Babbage interpreted this project as providing a sort of proof that mental labor too could be subject to the division of labor. The important thing to note is that Babbage recognized the importance of this, and coupled it with the intellectual developments at the time in the Great Britain around the controversies of the interpretation of the algebraic developments of Boole and De Morgan. After all, for Babbage the importance of Boole's algebra was that it showed that thought could be reduced to symbolic operations, and these could be mechanized through devices such as his Engines.

3

Trifling Pins & Untutored Calculators

3.1 INTRODUCTION

A Revolutionary monument to Reason was under construction at the nearby Bureau de Longitudes to supplement the metric system (which had been inaugurated as nature's own measure, eternal and immutable). Although originally commissioned as part of the Cadastre of France, launched in 1791, with Prony as director, the logarithmic tables were in fact never used for that purpose, having been expressly designed for the decimal division of the angles of the quadrant, which, along with the decimal division of time was later abandoned as part of the metric system.

Calculation had not yet become mechanical, the paradigmatic example of preocesses that were mental but not intelligent. Allied with the higher mental faculties of speculative reason and moral judgment, calculation was remote from the realm of menial labor, of the automatic and the habitual.

Astonishing feats of mental arithmetic were soon to beocme the province of the idiot savant and the sideshow attraction, no longer the first augury of profound mathematical gifts

Calculation took on the dull, patient associatoins of repetitive and ill-paid bodily labor, ranked as the lowest of the mental faculties.

3.2 PRONY BACKGROUND

Gaspard Clair Francois Marie Riche de Prony (1755–1839) was born in Cahmelet in the Beaujolais region of Southern France to a family of the provincial middle bourgeoisie–the social class that would fill the ranks of the Revolution and Empire's bureaucracy **picon_et_al1984**. After an education in the Classics, in 1776, when he was twenty-one, he entered the École des ponts et chaussées in Paris.[1] Prony's life coincides with a period of the institutionalization of French sciences and techniques with the foundation in 1794 of the École polytechnique–where he was appointed professor of analysis and mechanics with Joseph-Louis Lagrange–and the École normale supérieure, and a growing interest of the savants for applied problems, and the generalization of the application of mathematical formalisms.

3.3 BUREAU DU CADASTRE BACKGROUND

En 1790, l'Assemblée nationale décida de remplacer les anciens impôts par une contribution foncière assise sur le revenu net des propriétés (6). Elle suivait en cela les idées de l'économiste François Quesnay.

Créé en 1791, le Bureau du Cadastre fut supprimé par Napoléon en 1802, qui créa un nouveau Bureau du Cadastre en 1807, avec la mission précise de faire établir des cadastres parcellaires dans chacune des communes françaises (les impôts fonciers furent tou- jours en arrière-plan de ces missions cadastrales).

Perhaps opportunely, therefore, early on in the new decade de Prony set up a Bureau de Cadastre in Paris, to prepare a detailed map of France to facilitate the accurate measurement of property as a basis of taxation. In connection with this plan, it was decided that a very large set of logarithmic and trigonometric tables would be prepared.

Durant onze années, le Cadastre a réalisé deux sortes de travaux : des cartes et des tables. Nous montrerons ci-après comment ces tâches se sont substituées à l'objectif initial qui était de nature fiscale : établir la répartition de la contribution foncière.

On peut distinguer cinq étapes dans les onze années d'existence du Bureau du Cadastre. Lors de la première étape, le but du calcul de l'impôt foncier resta primordial – on a calculé la surface des départements. Lors d'une deuxième étape, on a calculé les grandes tables. Ce calcul s'acheva en mars 1795. À ce moment-là, Prony répondit à une demande d'édition de tables trigonométriques réduites, qui furent termi- nées en juillet 1795. La quatrième étape a été celle de la détection des erreurs de calcul et de

---

1. At that time, the École's tyros arrived with only the rudiments of arithmetic and geometry. Furthermore, instead of a definite curriculum and lectures, learning was done through self-instruction and direct practice in construction sites **picon_et_al1984**.

leur correction. Les grandes tables furent calculées une deuxième fois. Les vérifications se terminèrent au début de l'année 1798. Dans une cinquième étape, Prony fit encore calculer quelques tables, graver diverses cartes et dresser des exemples de cadastres communaux par type de culture.

Prony gave some details of the project in a 'Notice' read to the classe des sciences mathematiques et physiques in 1801, soon after it was finished. The personnel were divided into three sections according to the work they did. The first section contained a handful of mathematicians, including A. M. Legendre, C. A. Prieur de la Cote d'Or, and Lazare Carnot; the former two were also involved with the reform of weights and measures, and latter two also acted as influential political figures. They chose the mathematical formulae to be used for calculation and checking, and also considered the choice of initial values of the numbers or angles, the number of decimal places to be adopted in each table, and so on. The second section comprised several 'Calculators', including the mathematicians A. M. Parseval (of the well-known formula in infinite series) and the textbook writer J. G. Gamier, who determined the values, and the differences of various orders, that needed to be calculated. They also prepared a page of tables for the numerical work by laying out the columns of the chosen values and the first row of entries, and preparing the instructions on the preparation of the remaining entries on the page. These calculations were done by the third section, a large team of between 60 and 80 assistants. Many of these workers were unemployed hairdressers; one of the most hated symbols of the ancien regime had been the hair-styles of the aristocracy, and the obligatory reduction of coiffure 'as the geometers say, to its most simplest expression' left the hairdressing trade in a severe state of recession.Thus these artists were converted into elementary arithmeticians, executing only additions and subtractions.

When a page was completed, it was returned to the second section, to check the figures using formulae chosen by the first section. The project was run twice, in that two sets of each table were produced from different equations, so that each set could be checked against the other. By 1794 seven hundred results were being produced each day.

3.4 TECHNICAL DESCRIPTION

What was de Prony actually doing

The pivotal moment of this transformation was Prony's project.

Sous la Révolution, on a introduit la division centési- male du cercle en grades : il a donc fallu calculer les tables correspondantes. Prony, directeur du Bureau du Cadastre de 1791 à 1802, a dirigé le calcul des logarithmes rithmes des fonctions trigonométriques de 100 000 divisions du quart de cercle (avec quatorze décimales) et ceux des 200 000 premiers nombres.

Cette œuvre gigantesque est consignée dans seize volumes in-folio, établis en deux exemplaires restés à l'état manuscrit.

With the adoption of the decimal-based metric system, the Revolutionary government rendered all older trigonometric tables computed using traditional sexagesimal divisions of the circle suddenly unusable, at least for French geodesists and astronomers bound to the new system.

In his capacity as director of the French cadastre, Prony was charged in 1791 to create new tables to compliment the French metric system, tables which would awe contemporaries and posterity as "the vastest and most imposing monument of calculation ever executed or even conceived."

By his own account inspired by Adam Smith's paean to the division of labor in the first chapters of **smith1904_1**, Prony organized the pyramidlike "monument of calculation" by means of a pyramid of tasks.

At the apex were a handful of "excellent mathematicians" [*géomètres d'un très grand mérite*] who would devise the analytic formulae to be used of the calculation; below them seven or eight "calculators" [*calculateurs*; sometimes also called *algébristes*] trained in analysis who would deduce form these formulas the numbers needed to begin actual computations; and at the base were seventy or eghty perons [*individus*; also *ouvriers*] knowing only the rudiments of arithmetic who would perform millions of additions and subtractions and enter the values by hand into ruled folio volumes specially laid out of the purpose. By means of these "manufacturing" methods, as Prony later called them, two copies of the tables, each consisting of seventeen manuscript volumes plus instructions, were completed by 1801.

In so doing, it pushed calculation away from intelligence and towards work.

Eighteenth-century usage of the term intelligence overlaps but odes not coincide with its twentieth-century meaning. Both denote mental agility, particularly in problem solving and learning.

For Condillac and his followers, analysis was simultaneously a method for investigating the minds' operations and a description of those operations. The healthy mind, unperturbed by passions or an unruly imagination, was endlessly taking apart its ideas and sensation into their minimal elements, then comparing and rearranging these elements into novel combinations and permutations.

> For Condillac, d'Alembert, Condorcet and other philosophes, thought was a combinatorial calculus, and intelligence therefore proficient calculation

Force of mind, individual or collective, was at the bottom the ability to analyze, compare, and recombine ideas, just as arithmetic was "the art of combining [numerical] relations."

Calculation set off moral as well as intellectual resonances for Enlightenment philosophers. Key to the moral revaluation of the interests was the belief that they involved self-discipline as well as self-interested calculations and therefore produced reassuringly calculable conduct. Avarice might not be noble, but it was at least predictable and therefore reinforced the orderliness of the social order.

> Some Enlightenment writers fortified this faint praise and attempted to recast all moral judgments, even the most laudable, as calculations. Francis Hutcheson thought the "Moment of Good" produced by any given act might be reckoned as the product of benevolence and ability; Jeremy Bentham insisted that his sums and differences of pleasure and pain were "nothing but what is the practice of mankind, wheresoever they have a clear view of their own interest.". (**daston1994**)

Work and mechanical were closely linked in both French and English usage until the middle decades of the nineteenth century, and the middle term that joined them was the laboring body. Work taxed the body but not the mind; even the most deft manipulations of "rude mechanicals" were ascribed to habit and instinct rather than thought.

> Most of those who engage in the mechanical arts have embraced them only by necessity and work only by instinct. Hardly a dozen among a thousand can be found who are in a position to express themselves with some clarity upon the instrument they use and the things they manufacture. (**daston1994**)

Here d'Alembert repeats a commonplace: skill, the knowledge of the hand, and habit, the enemy of reflection, had long been opposed to intelligence and deliberation, and intimately associated with manual labor.

> Il est intéressant de faire ici le rapprochement des définitions que donne l'Encyclopédie de l'« artisan » et de l'« artiste » (t. I, p. 745) : le premier est « le nom par lequel on désigne les ouvriers qui professent ceux d'entre les arts mécaniques qui supposent le moins d'intelligence. On dit d'un bon Cordonnier que c'est un bon artisan, et d'un habile Horloger que c'est un grand artiste ». Par « artiste », on entend les « ouvriers qui excellent dans ceux d'entre les arts mécaniques qui supposent l'intelligence ; et même à ceux qui, dans certaines Sciences, moitié pratiques, moitié spéculatives, en entendent très bien la partie pratique ; ainsi on dit d'un Chimiste qui fait exécuter adroitement les procédés que d'autres ont inventés, que c'est

> un bon artiste ; avec cette différence que le mot artiste est toujours un éloge dans le premier cas, et que, dans le second, c'est presque un reproche de ne posséder que la partie subalterne de sa profession ». — On voit que nous sommes encore fort loin des contenus et résonances actuels. (**friedmann1953**)

> Prony himself remarked upon the social oddity represented by "the quite singular gathering of men who had had such different existences in the world" and upon the intellectual anomaly that the fewest computational errors were made by those "who had the most limited intelligence, an automatic existence, so to speak". (**daston1994**)

Calculation had up to that point been an intellectual occupation fit for the fines minds and the best society.

Si la démarche de Prony demeure isolee, dans un contexte de production encore largement traditionnel, elle marque tout de même l'ouverture d'un novueau front. L'organisation du travail devient raient une affaire d'ingénieur, même si le cahntier ne suit pas le mouvement, et si l'industrialisation se fait encore attendre.

Les tables du Cadastre prennent une connotation tout aussi politique que scientifique. Les méthodes employees pour venir à bout de cette tâche gigantesque traduisent qant à elles des enejxy de rationalisation sociale. Concrètement, cette divsion du travail se manifaste par une organisation hiérarchique des compétences.

3.5 CONCLUSION

4

Mechanizing Thought

4.1 INTRODUCTION

Indeed, soon afterwards, in a pamphlet of 1822 on 'the application of machinery to the purpose of calculating and printing mathematical tables'—his main publication for securing governmental support for production of the Difference Engine–he gave some account of de Prony's project and noted that mechanical methods would speed up the process of calculation. Clearly he was struck by de Prony's production of the tables following an industrial process, and was hoping to imitate the process by mechanical means. In his book on manufactures, he rehearsed some of the same material on de Prony's project and on mechanical calculation.

Thus his contribution was to substitute manual labour by engineered automation in the construction of tables.

This section describes the reading that Charles Babbage makes of de Prony.

The distinction between the realms of mind and matter, and the appended distinction between the "introspective" and "hypothetical" modes of enquiry, will prove to be of fundamental importance to understanding the puzzled or straightforwardly dismissive reactions to Jevons' transgression of the fields of the natural and moral sciences.

But this did not make the phenomena of the mind suited to be analyzed by means of the same tools and methods as those of matter. Mind and matter were considered categorically distinct phenomena. To invoke mechanical analogies thus at no point forced the political economist to investigate the mind with the same tools of research as nature. Indeed, Mill regarded mechanical analogies for mental phenomena with distrust.

Halfway through the nineteenth century, the categorical distinction between the phenomena of mind and matter vanished under the influence of developments within psychophysiology. This enabled economists such as Jevons to transgress the boundaries traditionally set to the tools of the natural sciences might be used to disclose the laws of the mind.

De Marchi (1972, 350) refers to this last mode of reasoning as "mechanical reasoning", a term I consider completely apt to pinpoint Jevons's specific contribution to the formation of modern economics. De Marchi apparently used it to refer only to Jevons's use of mathematics in economics.

The index of truth of these experiments was twofold. First, the experimental results should "mimic" nature's complexity–but this was only so for the informed eye that understood the causal mechanism embodied in the experimental results. Second, the ultimate criterion of truth was a mathematical rendering of the experimental results–that is, a mathematical function makes the mechanism explicit of the production of the experimental observations.

They all form instantiations of Lord kelvin's dictum (Thomson [1884] 1987, 111, also 296) that we can only understand something if we can make a mechanical model of it. Babbage's Difference Engines and the new formal logic developed by Boole, De Morgan, and Jevons were driving forces in the development of mechanical reasoning in all these senses.

4.2 BABBAGE'S ENGINES

Babbage's calculating engines project emerged out of a growing need for precise and accurate tables by the quickly industrializing British economy. These tables were necessary, among other things, for navigation and for insurance companies that were rapidly growing in importance.

There were so many faults that could be made in the production of numerical tables, in the computations of the "avalanche of numbers" comprised in them, in the copying of the outcomes, and in the various stages of the printing process that Herschel and Babbage spent many hours checking these tables themselves for their own scientific purposes. One one such occasion, as the story goes, Babbage exclaimed in exasperation that the wished these computations had been made by "steam" (see for example, Swade 2000, 15).

Also, the necessity of speeding up the process of calculation was an important factor in all of Babbage's endeavors to "compute by steam". Indeed, in many ways as will be seen, the mastery of time was one of the driving motives and major problems in Babbage's engines project.

Good calculators, in many cases autodidacts extraordinarily gifted with calculating capabilities, were valuable and hard to find.

Precision, accuracy, and time were the important factors posing severe constraints on the construction of the requested tables. It is well-known how Gaspard de Prony's calculating project, commissioned by the French Revolutionary regime to facilitate the conversion to the decimal system, gave Babbage the clue in how to solve these problems jointly by the use of machinery. Political economy provided the means to solve this seemingly impossible task. Accidentally reading Adam Smith's *Wealth of nations*, Prony immediately realized the importance of Smith's principle of the division of labor and split up the work into three different task levels. In the first, "five or six" eminent mathematicians (including Lagrange and Prony himself) were asked to simplify the mathematical formulae to polynomials. In the second, a similar group of persons "of considerable acquaintance with mathematics" adapted these formulae by the method of differences so that one could calculate outcomes by simply adding and subtracting numbers. This final task was executed by a large number of unemployed hairdressers. The work of this last group of computers or calculators, as they were commonly referred to, can be rightly seen as a *reductio and absurdum* of manual computation (Grattan-Guinness 1992, 40 ; see also Grattan-Guinness 1990c).

Prony's approach showed Babbage that it was possible to mechanize not only physical, but also mental, labor. His interest in the French project fits into his wider perception of algorithmic procedures in "mathematics, science, and other walks of life" (Grattan-Guinness 1992, 34). Babbage emphasized in *Machinery and Manufactures* ([1835] 1963), still one of the most fascinating studies on the emerging mechanization of the economy, that the lowest task of Prony's project was "almost" a form of mechanized mental labor. Babbage designed his Difference Engine to mechanize this lowest stage of computing. Its method of computation ingeniously incorporated the method of differences in its wheels and gears, hence its name. Babbage's Difference Engine promised to fulfill all requirements Herschel and Babbage had been lamenting about : It saved calculation time and produced accurate and precise numbers. The computations would be more accurate than when done by a human individual–for machines, as opposed to humans, were thought not to make unpredictable mistakes. An attached printer would prevent errors in transcribing the outcomes. By thus excluding human interference from the whole process of computing and printing, all sources of faults–human faults–would be prevented, and the numbers would be precise, accurate, reliable, and reproducible. All this, of course, was based on the assumption that the machine itself operated flawlessly, a matter of great concern to Babbage. For all his calculating engines, he designed automatic checks and stops to secure its proper working.

Prony's approach affected the traditional view of the hierarchy of mental and physical labor, Before Prony started his table project, computations were, for the most part, made by mathematicians themselves for their own purposes (Warwick 1995, 317–8). The routinisation and then mechanization of computing downgraded calculation to the lowest of mental activities, thus equating it with the routine labor executed in the emerging factories. Babbage exploited the comparison of calculation with routine factory labor in straightforwardly paralleling Prony's division of tasks with the division of tasks necessary for the construction of a "cotton or silk-mill". The "multitude of other persons" (the calculators or their mechanical equivalent) used in their employment the "lower degree of skill" (Hyman 1989, 143).

The British Government commissioned Babbage in 1823 to construct a calculating engine. When the government stopped its funding in 1834, it had furnished a total sum of £17,470—an astronomical amount of money when compared with the costs of a first-class locomotive such as the *John Bull*, which only cost £784 7s.

For practical purposes, a much simpler contrivance, the so-called arithmometer invented around 1820 by the French army officer Colmar, was of much more use. This arithmometer, rather than Babbage's engines, became part of the standard inventory of the first mathematics laboratory of Whittaker in Edinburgh at the end of the century, where their careful routinized use by scientists served the purposes Babbage dreamed of with his calculating engines.

This museal arrangement symbolizes a perfect division of head and manual labor, of industry and mind, in which are nonetheless embodied the very same principles of the lever.

With Babbage's Difference Engine, thoughts on machine intelligence were really only speculations, for it was obvious that the calculating capacities of the machine still involved a considerable amount of separate mental activity that was not captured in mechanical terms. The development of an even more ambitious machine, the Analytical Engine, seemed to overcome these limitations. The new contrivance derived its name from its ability to perform all ordinary analysis.

In contrast to the Difference Engine, the Analytical Engine could be really programmed. In fact, as is well-known, the design showed great similarity with von Neumann's computer design a century later (see Swade 2000). The comparison Babbage made with a silk mill, in *The Economy of Machinery and manufactures*, should be taken literally ; the Analytical Engine incorporates in its design the architecture of a factory. The Analytical Engine combined the calculation of various functions without the interference of human mind and hand. This was attained by the use of punched cards, an idea that Babbage got when he was working on his book. The idea originated from the famous Jacquard loom, in which a complex mechanism of levers regulated the lifting of the warp in accordance with the desired pattern. This was done by triggering the right set of levers by a role of punched cards. These cards activated a system of levers to lift the intended column of gears. Lovelace famously wrote that "the Analytical Engine *weaves algebraical* *patterns*, just as the jacquard-loom weaves flowers and leaves" (Hyman 1989, 273).

4.3 THE COGWHEEL BRAIN

Babbage, writing of the project in 1832, was still obliged to admit that his claim "that the division of labor can be applied with equal success to mental operations" would "appear paradoxical to some of our readers." The labor of mechanicals emptied the task of intelligence ; yet the task at issue, calculation, had been understood to be the very essence of intelligence.

Babbage's reading of Prony's project as akin to setting up a silk mill was technically correct, but the metaphorical silk mill was of the sort to be found in late eighteenth-century Lyon, not early nineteenth-century Manchester. Babbage's misreading of Prony's "manufacturing" methods paralleled the very different meaning of *manufacturing* in France and in England at the time.

Babbage understood the machines in question to be the legion of artisan computers whose undeniable status as "mechanicals" served him as an existence proof that any mental operations they could execute could also be executed by a machine. Prony's division of labor had simply clarified which operations those were. In contrast, Prony's machines was the entire system of calculation, keeping with the image of the machine as a system of parts whose hierarchical organization was governed by the principle of the division of labor.

For Babbage, Prony's repeated appeal to "manufacturing methods, his emphasis upon the rapidity with which his calculators produced logarithms, his description of their labors as "purely mechanical operations" all irresistibly suggested an automated factory regimen geared to productivity (N, pp. 6, 8n ; NTL, p. 9).

> Hence Babbage quite naturally undertook to replace the workers who executed the mechanical operations with actual machines, to scale down both the first and second sections of mathematicians and calculators in order out save on the costs of expensive skilled labor and out conceive of these automated, more efficient arrangements as an ongoing production of calculations, spewing out tables at the pace and in the quantity that the spinning jenny spun out thread. (**daston1994**)

Jevons's approach to the moral realm only made sense once psychophysiology and formal logic gained ground.

Originally, mechanical reasoning referred to the use of simple machines to disclose the wonders of the universe. It had its origin in the mixed mathematics tradition that went back to Archimedes, and that was very important in the scientific revolution of the sixteenth and seventeenth centuries.

In Machamer's reading, mechanical reasoning might equally well be labeled the Galilean approach to science. Machamer compares the role of Galileo's simple machines to Kuhnian exemplars. An explanation of a natural phenomenon can, by analogy, be deduced form the mechanical principles embodied in these contrivances, and this is what Galileo consistently attempted to attain. without any doubt, in his view, Galileo's training in mixed mathematics played an important role in this new approach of how to gain knowledge of nature. members of the "mixed sciences" (*scientia media*) came to denote themselves as mechanical philosophers.

The use of simple contrivances like the balance as a mode of comprehending nature–in a similar fashion as a Kuhnian exemplar–also involved shifting criteria of proof and evidence. ...These ingredients for Machamer add up to a "clear moral" : "To get at the true cause, you must replicate or reproduce the effects by constructing an artificial device, so that the effects can be seen" (69).

In mixed mathematics, geometry was used to understand the working of simple machines like the balance, the inclined plane, and the pendulum. Ironically, the Difference Engine was admired more as an edifice of reason and engineering than for its practical usefulness. Schaffer and Swade both relate how this little fragment showed its "devil's tricks" during Babbage's popular soirees. It moved Lady Byron, the mother of Ada Lovelace, to describe the Difference Engine as a "thinking machine".

Babbage was well-aware of the speculative vistas opened up by his machine. He never tired of telling his visitors that what seemed so miraculous and amazing to them had been programmed by him beforehand. Babbage was so content with this that the developed this idea more generally to refute Hume's argument against miracles. The regular–irregular output of the machine did not fit into Hume's idea of causation as a regular sequence of events–the punchline of Hume's argument–and yet this output was produced by the actions embodied in the mechanics of the calculating engine. Could it not be, so Babbage wondered, that all apparent irregular sequences in nature were governed by mechanical laws ? God, Babbage argued in his unsolicited *Ninth Bridgewater Treatise*, was the programmer of nature, who imposed mechanical laws on it, even if we, as limited human beings, were not always able to decipher them.

Whewell, as seen previously, retreated from French rational mechanics because he considered its mathematics too deductive, too much a storage system of knowledge that was not in contact with physical reality and, hence, not fit as an inductive instrument of enquiry. But his firm belief in the providential order of nature was an important factor as well. Induction could, and should, unveil the laws of nature and thus show the providential order. This was what taxonomies–like those of Linnaeus, but also his own geological taxonomies–produced ; the ultimate cause revealed in such taxonomies was the superior providential order in nature.

Babbage found it "difficult to interpret" Whewell's thoughts on the limits of mechanical enquiry and used his engine to give full force to the new French mathematics of Lagrange and Laplace, as the "theory of invention" he had been looking for from the days of the short-lived Analytical Society : Mathematical analysis, in the *Bridgewater Treatise* exemplified by Laplace, showed that miracles, probability, and free will all could be approached as the same issue.

Babbage's arguments against Whewell spilled over into the inner province of the mind. What reason was there to suppose that the human mind functioned in a different way from a calculating machine ? Consciousness and freedom of the will, to name the two great puzzles of the mind, could be mere specters in the machinery of the mind. What the individual perceived as an act of free will could basically be governed by the same laws that produced the miraculous jump in a string of numbers. Equally, consciousness could be the by-product of the invariable mechanical laws of nature. Babbage's work on his calculating engines thus "governed," as Schaffer rightly claims, his "stories about machine intelligence" (Schaffer 1996, 62).

Babbage went even further to argue that it would be presumptuous to postulate any knowledge over and above what our mathematics and our machines showed to us to argue for any non-mechanical insights.

Babbage's severe blow to traditional categories of natural theology and moral philosophy was only convincing, however, on the assumption that the caprices of his calculating engines served as analogies to the world at large, the natural and the moral, which is more or less a definition of mechanical reasoning : to understand the world by means of machines. The Difference Engine thus genuinely functioned as an engine of discovery. All laws of nature, in the end, might be as mechanical as the laws governing the engine itself. To search for these laws was to search for an algorithm producing the plethora of concrete events. Such an algorithm is a machine. The calculating engine and French rational mechanics proved to Babbage that nature and mind were no more than complex computational machines. There was no place for Whewellian "intuition" here.

4.4 CONCLUSION

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Conclusion

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Conclusion

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