SUMMARY of IDEAS DISCUSSED YESTERDAY (17TH APRIL 2020)

This is a summary of the discussion we had in yesterday's online tutorial (ie., on 17th April) which will be helpful for writing the essay.

(1) EXAMPLES & EVIDENCE regarding SCIENTIFIC KNOWLEDGE & INQUIRY

The question of what kind of evidence and examples should be discussed on this topic was asked. So I asked everyone in the class to start listing examples of scientific advances, and we had an extended discussion over these. Here are the examples, with some discussion points:

- **Discovery of penicillin (Fleming):** discovery was largely accidental

- **Model of the atom:** this was a long process, involving chemists like Dalton, theorists like Einstein & Bohr, the experimental discovery of the nucleus by Rutherford, and finally the theory of quantum mechanics which explained everything.

- **The biological cell & its structure:** This has a very long history, from the discovery of cells by Leeuwenhoek and Hooke, to the early theories of Schleiden & Schwann, and the subsequent work in elucidating all their properties over the last 150 yrs or more.

- **DNA double helix discovery (Franklin, Crick & Watson):** the story of this is well known (see my slides for a summary).

- **Discovery/invention of theory of General Relativity (Einstein):** this was done single-handedly (see my slides for a summary).

- **Understanding of supernovae:** these have been observed for many centuries. The first understanding of what they were was from Baade & Zwicky, but it took many years, plus the discovery of quantum mechanics and the development of relativistic astrophysical theory, before a true picture of what they were emerged.

- **Creation of vaccines (Jenner):** there is a long history here, going back maybe 100 yrs, long before Jenner & later Pasteur made vaccination widespread. The first real understanding of how it worked only came in the 20th century

- **Discovery of rules of inheritance of traits (Mendel):** This was work done in isolation by Mendel, and not known by the outside world for another 40 yrs.

- **Theory of continental drift (Wegener):** You will be familiar with this from class. The idea is many centuries old but was first elaborated in detail by Wegener. It was not widely accepted until a plausible mechanism for it was proposed.

- **Discovery of/theory of genetic coding (Crick, etc.)** The basis of the code was clear once the DNA structure was discovered, and noted almost immediately by Gamow and Crick. It took 20 yrs and many experiments to confirm and flesh out the mechanism.

- **Discovery of/theory of Quantum Electrodynamics (Dirac, Tomonaga, Feynman, Schwinger, & others):** this was a key problem after the discovery of quantum mechanics – how to use it to describe the interaction of light and matter. It led to the formulation of "quantum field theory", now a fundamental part of physics.

- **Invention of Psychoanalysis (Freud):** largely developed by Freud, although his ideas also used results from clinical work of Breuer et al. Some dispute how scientific this field really is.

- **Discovery of neurons (Ramon y Cajal): experimental** discovery with subsequent elaboration of theoretical picture.

- **Discovery or/theory of circulation of the blood (Harvey):** Harvey is often credited with his work in 1628, but in fact many things were known even long before the pioneering work of the Galen in the 2nd century AD. So one has to be careful of the history here.

- **Placebo effect:** discussed since the 18th century, the question of its existence/importance, and what might lead to it, is still controversial.

- **Discovery/invention of classical mechanics (Newton)** Largely invented by Newton, relying partly on extensive data on planetary and lunar motion; it revolutionized physics and set the pattern for how theories were to be formulated (in terms of mathematically formulated laws) for centuries thereafter.

- **Theory of Quantum Mechanics:** this theory grew in stages over 25 yrs, starting from Planck and finishing in the theory as formulated by Heisenberg and Schrodinger. It would not have been found without extensive experimental pointers leading to it. See slides for extended summary. This is probably the most important scientific advance in all of history, given its consequences for the rest of physics, chemistry, and biology, and indeed for all of science.

- **Discovery of patterns of planetary motion (Kepler's Laws):** This relied on very extensive observations by Tycho Brahe, and Kepler's faith that there had to be mathematical regularities underlying the data.

Note that this is only a very incomplete list, and is biased by the discussion we had, and in fact the discussion was strongly biased towards physics, astronomy, and biology. There is no mention of mathematical advances – without which much of science would have been impossible – and almost no mention of chemistry. Other more recent and less quantitative sciences like geology, psychiatry, etc., hardly get a mention. On the other hand it might be argued that insofar as these other sciences are recognizably scientific, they are based on the harder sciences (this is no excuse however for neglecting mathematics). Clearly you need to use examples like these – AND you need to research them properly before doing so.

(2) **EXAMPLES of NON-SCIENTIFIC KNOWLEDGE & INQUIRY**

We discussed a number of these. Here are the main examples:

- **The LAW/JURISPRUDENCE**: Here we have, in every country, some body of laws (a legal framework); this framework varies widely between countries. It has grown up over thousands of of years. The system is administered by police, courts, and by the government/legislative body. Apart from the legal system – of which extensive knowledge is required by judges, lawyers, the police, the government, and up to a point the general public – there is also typically a body of "legal principles" underlying the whole thing. And amongst the principles there will be various moral/ethical principles, as well as more general philosophical principles (which are sometimes religious as well). To administer the legal system is complex, and it also require investigative inquiry/detective work by the police (and in many countries also by the courts), in order to establish the truth or falsity of legal claims. This investigative work often involves different kinds of evidence.

- **ETHICAL/MORAL SYSTEMS**: These exist in many countries, and are often underpinned by various ethical philosophical systems, and by ethical and moral principles. These are often written down in sometimes quite complex form, and can have an influence on legal systems.

- **RELIGIOUS SYSTEMS:** These have existed since before recorded human history, and have come in a huge variety. In the last few thousand years they have also involved elaborate writings which formalize their principles, with codes designed to guide or govern different human activities, and extended discussion of moral questions and principles. There is thus, in many cultures, an overlap with parts of both the legal and ethical systems.

We also discussed briefly the following topics/areas of activity:

- **ASTROLOGY**: For thousands of years this was intimately linked to astronomy (some branches of astronomy and physics like cosmology have only recently detached themselves from astrology). Astronomy detached itself from astrology primarily through the role of observation and theory (the latter eventually becoming part of physics).

- **HISTORY**: This is a subject which is of course largely based around "historical evidence" and facts, but with a large focus on understanding how and why things evolve as they do – there is thus lots of theory in the subject as well. It involves extensive investigation of documents, a strong emphasis on methodology, and of course a huge corpus of knowledge.

- **MUSIC:** This is usually considered to be an art, but note that in many cultures it also involves extensive theory, in the structure of music and its composition. One often talks of "musical experimentation", and "improvisation", usually within some more or less established framework – but new musical genres are frequently being invented. The role of

the different kinds of instrument and their design are clearly important, as is the link between music and other art forms (notably dance).

Clearly ALL of the above disciplines have components to them that we also see in science – but NONE of them are usually considered to be sciences. So if you want to understand what makes an activity scientific, or what makes a body of knowledge scientific, you need to understand why the above activities are NOT scientific as well.