Ravetz, Jerome R.

[I wish to concentrate my remarks...]

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arithmétiques, mais il ne me semble pas que cette invention technique ait influé sur le développement des mathématiques.

La véritable application des mathématiques aux problèmes concrets posés par la physique et la technique nécessite la résolution d'équations différentielles, et d'équations aux dérivées partielles, ainsi que le recours aux principes du calcul infinitésimal, du calcul des variations et des autres branches de l'analyse mathématique. Ce n'est donc qu'à partir de la fin du XVII[e] siècle, lorsque les éléments de ces disciplines auront été progressivement découverts que l'on pourra envisager une application des mathématiques aux problèmes généraux les plus élémentaires posés par la physique et par le développement des techniques et ce n'est guère qu'au XIX[e] siècle que les mathématiques deviendront l'un des principaux outils du progrès technique, la technique étant elle-même pour les mathématiques une incomparable source d'inspiration.

J. R. Ravetz

I wish to concentrate my remarks on the middle period discussed by Professor Daumas. From the list of sciences penetrating techniques that he gives, one can see a series: Mathematics, Astronomy, Physics, Chemistry, Biology. It is in such an order that sciences achieve advance to a new stage of development, or in this case, penetrate technique.

We can learn some things from a study of this list. First, this is the series of effective penetration, and it is not the same as the series of attempts at applying science to practical matters. Chemistry and Geology are two good examples of where the attempt was made, and failed. Other examples are in the dreams and programmes of the Royal Society of London. Napoleon once said that defeats are more instructive than victories, we should learn how to use this maxim for our own work.

It seemed to me on reading the paper of Professor Daumas that he stressed, perhaps too much, the limited extent of the penetration of science in this middle period. To be sure, most of techniques continued to be unaffected by science. But the few successful applications of science were of the greatest importance. Navigation is an obvious example. Another example is the steam engine. It has been said for many years that science owes more to the steam engine than the steam engine to science. This is true with one exception. The idea of the possibility of vacuum engine such as that of Newcomen and Watt, comes from the studies of natural philosophy of the XVIIth century.

One final point on the series. At the end is Biology, and there science has not yet conquered. Even in the technology of textile manufacture,

my colleagues at the University of Leeds are frequently in the position of trying to explain why the craftsmen succeed with their techniques. And in the bio-siocial sphere, such as in agriculture, the difficulties are even greater.

My last comment concerns the effect of technology on science in the middle period. To be sure technology provided problems and instruments to science, but there was something even more important: a basic component of the new idea of "science" which was advanced by the founders of the "mechanical philosophy". The case of Bacon is well known. I would remind that Descartes used *Dioptics* as an illustration of his *Method;* there he started with physical theories of light and vision, proceeded to the mathematical problems of the shape of lenses, and concluded with specifications for a lens-grinding machine.

D. J. de Solla Price

I should like to add a footnote to the words of Professor Daumas on the problem of technology (French *technique).* It seems to me most useful and important to distinguish between two lines, practically distinct and different in their historical character. It is a matter of Low Technology and High Technology. As for the Low Technology, it is an uncomfortable fact for the historian that writing and the written language are comparatively late pieces of technology.

By the time of this development and, by definition, the end of prehistoric times, man had already acquired quite complex techniques for housing, agriculture, waterworks, leather tanning, dyeing, metal work, weapons and all sorts of tools. Starting on the most early times at such a high level, subsequent change was quite gradual and slow until the Industrial Revolution. With High Technology it is a quite different matter. Beginning quite early, but flowering in Hellenistic times, there grew up a special devices technology of scientific instruments — astronomical devices, planetary and other automata, astrolabes and geared machines for calculation and demonstration. It is specially interesting that much of this history is attested not from texts but rather from extant artifacts in our museums. What is important about this artisan tradition is that it gives rise directly to the medieval and renaissance schools of clockmakers and other mathematical practitioners. These are most important, not only because they dominated the experimental philosophy of the XVIIth and later centuries, but also because they are the tradition from which spring the mechanical techniques of the industrial revolution.