GRESHAM

COLLEGE

THE LEGACY OF SIR THOMAS GRESHAM

SIR THOMAS GRESHAM: THE SPIRAL OF KNOWLEDGE

A Lecture by

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GRESHAM COLLEGE QUATERCENTENARY LECTURE

Sir Thomas Gresham - The Spiral of Knowledge

1. Gresham's Dream

Sir Thomas Gresham's dream was for knowledge to be developed and usefully applied - but he could not have dreamt of the prodigious scale of the expansion of knowledge over four centuries.

This lecture could not realistically attempt a 400-year survey of what Gresham called the 'New Learning', even restricting this to the traditional Gresham subjects. Instead, it is about how attitudes to knowledge have developed over the four centuries - and, in particular, how - from the drive towards the organisation of knowledge - there has developed the modern science of information. As will be seen, this is a development in which City University, with its internationally-recognised Department of Information Science, has played an important part.

In order to guide us through what would otherwise be a rather abstract field, I have chosen to illustrate our attitudes to knowledge in an unusual way: by using what, in Sir Thomas Gresham's time, would have been called a 'conceit'.

It happens that in the very year which we are celebrating - 1597 - there arrived in this country from Italy an unusual and significant board game, the Game of Goose. It was duly registered by John Wolfe at Stationers Hall as '.. the Newe and Most Pleasant Game of the Goose' on 16 June 1597. We do not have the registered copy of that game itself but a somewhat later (c.1640) Venetian version of the game is shown in the illustration. It is a spiral race game, played with double dice and the usual tokens, the aim being to arrive at the final 'square', numbered 63. It is generally held that this game was devised in Italy and, towards the end of the sixteenth century, was sent by Francesco de' Medici (1574-87) as a present to King Philip II of Spain, and then took hold elsewhere in continental Europe, where it is still played.

What was the fascination of this Royal Game, enjoyed by monarchs and yet so widely diffused? It appears a childish thing at first sight, rather like snakes and ladders. The favourable squares are those with geese, where you double your score forward. Then there are seven hazards, such as the labyrinth, the ale-house and the prison where you must spend time - even a death's head, from where you must return to square one.

Yet, on closer thought, there are deeper points of interest. It is obviously a 'game of human life', evident in the choice of hazards. And, consistent with this, the number 63 has profound numerological significance, being the grand climacteric number of the cabbalists, representing the 'year of years' in life. The placement of the geese and of the hazards is again consistent with a deep numerological scheme. This 'game', then, was probably seen at the time of its devising more as a way of predicting the fortune of the player, or maybe indeed of influencing it.

It serves as a reminder that 1597 was a time when the clear forward path of science was not fully signposted, a time when astrology was still respectable. Sir Thomas Gresham's vision in its concentration on useful, rather than arcane, knowledge was by no means an insignificant statement therefore.

Our Game of Goose, with its spiral track, will serve us as a general metaphor for the development of knowledge. But it also looks forward in a more particular way. One of the fascinations of the game was that it was modelling the future. Indeed, one can imagine variations of the game that could be played quantitatively by modern actuaries in the City, determining how likely it is that you will reach pensionable age! The Game thus serves as a frame of reference for viewing the development of knowledge in the Renaissance, reminding us of its arcane past and of its scientific future.

2. Science and the Exponential Growth of Knowledge

It is to the development of science in the 1600s that we now turn. In this period, Gresham College has a proud role both in the development of applied mathematics and in fostering the Royal Society. Interestingly, despite the force of scientific advance, not all the knowledge gathered by the Royal Society - for example in its journal - was truly scientific. There were still anecdotes of wonders, signs and arcane knowledge. The museum of the Society, housed at Gresham College, [Grew, Museum Regalis Societatis, 1681] was not free from these influences:

> - a piece of bone voided by Sir W Throgmorton with his urine, about the bigness of a little green pea (given by Thomas Coe Esq)
>
> - the rib of a Triton or Mereman
>
> - the thick Gogle-eyed beetle (not to be confused with the long Gogle-eyed beetle).

However, the driving force of science is not the collection of wonders but the intellectual fascination of making mental models of the real world. This, the true light of science, is well exemplified by Sir Isaac Newton, at his home in Woolsthorpe in 1666. It was there that he began to consider gravitation extending beyond the Earth to the orbit of the moon and - having formed this mental model - performed the all-important step of quantification of its predictions. He compared the acceleration of the moon in her orbit with that of the gravitational attraction of the Earth, 'diminished by distance' - the famous inverse-square law - and when he compared those accelerations, he 'found them answer pretty nearly'. There could scarcely be a more apt demonstration of the role of knowledge as the hand-maid of science, supporting through observation and experiment the choice of the successful mental model, and causing unsuccessful models to be rejected. Even though Newton had to go through several more stages before finally being satisfied with his theory, the concept of universal gravitation was born.

Through the scientific process, there was a powerful means of separating 'useful' models from 'un-useful' models. It is important to understand, though, that in this process, the label 'useful' applies to the model and not to the nature of the knowledge itself: there is nothing to guarantee that good models of the world have useful applications, though often they do. Gresham, being a merchant at heart, no doubt thought of knowledge that would be useful - say - to sailors or tailors: it is not likely that he would have seen profit in the inverse square law!

Also, the process of science was not one of continuous advancement: there were pitfalls on the way - and much going back to square one! Nevertheless, knowledge advanced - and as it advanced, so it grew. Science, as a knowledge factory, had come on stream.

It is interesting to show this growth by a spiral diagram: in this, the 'clock' goes round once every hundred years. The distance from the centre represents (approximately) the number of scientific journals in the world up to about 1950 and, thereafter, an extrapolation of the same rate of growth. It shows that science - as a factory of knowledge - sprang into being (perhaps with Newton's Principia in 1687) and that knowledge then expanded exponentially, growing by a factor of 10 every fifty years, up until about the middle of the twentieth century, by which time the cumulative number of journals founded world-wide had reached about 40,000 journals [D de S Price, Science Since Babylon, 1961]. It is a characteristic of exponential growth that it cannot go on for ever and it is reassuring that we are reaching the limit: the number of journals seems to have stabilised at about the 1960 figure. The predicted number of journals by the millennium would have been nearly a million, as shown by the spiral diagram! [D Goodstein, NCAR Symposium, 1994]. Other measures of the amount of knowledge similarly show this pattern of exponential growth, with a slow-down beginning around 1950-1960.

3. The Systematisation of Knowledge

The exponential growth of science from the late seventeenth century meant that there was - quite suddenly, in historical terms - a lot of knowledge and it was the task of the 18th and 19th century to systematise it for use.

One immensely powerful tool in the systematisation of knowledge was the development of taxonomy: the discipline of classification, taken to its highest point in the splendid ramifications of the biological schemes developed in those centuries to deal with the huge variety of nature.

But in the physical and mathematical sciences another process of abstraction was also developing, dealing with the complexity of nature by discovering ever-deeper connections. Examples of this include the work of French mathematicians such as Laplace and Lagrange, where a whole diversity of physical phenomena could be modelled - and therefore predicted - using a single set of equations, where the symbols took different meanings according to the nature of the problem.

It is amusing (though perhaps no more than that!) to trace similar developments in the Game of Goose in France, where the game became used as a means of conveying many different messages, while retaining its numerical and other structures essential to the playing of the game. For example, there is the 'Jeu des Guerriers Francais', in which the spiral track traces the progress of a soldier, from the departure of the conscript through his training and enrolment in the specialised branches of the army. In this version of the game, the favourable squares - the 'geese' - become the victories of Napoleon and the French Army: Marengo in 1800, Austerlitz 1807 and so on, arriving at the French star of victory at square number 63. Games of this sort were in fact used to encourage recruitment in the armed forces.

The model-building power of underlying theoretical frameworks, combined with the adaptability of symbolic representation was the main engine of the development of scientific thought in these centuries. Yet no-one had taken the step of using those techniques on the process of thought itself: no one, that is, until in 1854 George Boole (1815-1864, Professor of Mathematics at Cork 1849, elected FRS 1857) wrote his celebrated treatise, 'The Laws of Thought'. This is, by any standard, an amazing work and one which is central to the development of modern information science. Quite simply, his design was to take the laws of logic and thought-process, and to strip them of their associations with the classical logicians - all the apparatus of formal syllogism, for example - leaving only the bare bones in which propositions and statements were represented symbolically and could be manipulated by an algebra which had its own laws, different from those obtaining for the everyday algebra of arithmetical functions. As is well known, this new formulation of logic became, a century or so later, the foundation of computer logic, often styled Boolean in his honour.

Thus knowledge now had both an abstract mathematical foundation to aid its development and an abstract algebra to aid its manipulation.

4. The Unification of Knowledge

These advances, however, still left knowledge divided into the great traditional branches. Sir Thomas Gresham would have recognised their structure, even though he would not have believed the weight of fruit they now bore.

In the later part of the 19th century, some developments in the physical sciences were to change that. The striking example is the work of James Clerk Maxwell, who through his theories of the electromagnetic field, united two previously-distinct branches of physics: electricity and magnetism were henceforth to be regarded as different aspects of one underlying physical model. That was a model with truly astonishing predictive power, leading both to the discovery of new phenomena - electromagnetic waves in the radio spectrum - but also to further unification of the whole science of optics. In an important sense, half of Physics - perhaps the greater half - had become the study of waves.

Soon after, developments in atomic and sub-atomic physics - such as the discovery of the electron - meant that a grand synthesis of knowledge based on a particulate model of the universe could be attempted, in which - for example - the whole of Chemistry was comprehended.

The achievements, both scientific and technical, of the Victorian era were especially great in England and were mirrored in the development of educational games, based on the Goose principle, each having some clear didactic object in view.

An example of such games which well demonstrates the spirit of the age is Wallis' Game of Genius and Invention - produced and printed (as many of these games were) very near here: at Skinner Street, Snow Hill in this case..

The achievements were so great, and the unification of knowledge so successful and profound, that many informed commentators felt that the advance would be complete and that all knowledge - at least, all natural knowledge - would soon be comprehended in a grand structure, fully interlinked from the apex. But these certainties were not to last!

5. The Modern Era

Against this background of Victorian certainties, it is amazing that Lord Rayleigh, one of the greatest classical physicists of the era, could so clearly see the warning signs as: 'two clouds no bigger than a man's hand'. He referred to two experiments of the early 20th century, where the results were difficult to fit into the pattern of all else that had gone before. One of those experiments - the photoelectric effect - was to lead to the quantum theory; the other, a failed attempt to measure the speed of the Earth through the aether, would lead to Einstein's theory of relativity.

The complications of those theories are too well-known for rehearsal here. Sufficient to say that attempts to re-unify Physics have been ongoing: a full relativistic theory reconciling gravitation with quantum mechanics is still the holy grail of this work. In many ways, though, it was the philosophical effect of the new theories which was so shattering, in terms of the structure of knowledge. Concepts - the building blocks of mental models - had to be revised wholesale: time, simultaneity, position, speed, even existence of an entity all had to be re-thought.

It may be that the great scientific revolution of our own time - molecular biology and the understanding of the building blocks of life - will in its turn generate a similarly-fundamental revision of concepts.

6. Information Science

The fluidity of thought which typifies our century has required the development of equally fluid means of handling knowledge. Information Science is the name given to the new discipline, interested in principle in all the different kinds of knowledge transactions between human beings but, in practice. concentrating on those communication events which happen in a formal or public setting. This definition includes, for example, all the mechanisms on which science itself depends: publication, dissemination, libraries, retrieval systems. And it is wide enough to include some major unsolved problems, relating to distinctions between the kind of information which is recognisable only in terms of human interaction, and the meta-information about 'documents', with which the system is concerned and to which mathematical or logical models can be applied.

The emphasis of much of the work at City University, which was a pioneer in this new discipline, has been on computer based retrieval of information. Essentially, the problem is one of using the computer to search large volumes of material and come up with 'useful knowledge' - where 'useful' is defined by the requirements of the inquirer: information science tends to be rigorously uncommitted as to whether information is intrinsically useful, or even whether it is 'true'. In principle, the approach is for the inquirer to define, using relatively few words, what is the topic of interest: the computer does the rest. However, the quantity of knowledge available in the world is almost unimaginably huge: even to do a realistic test of the system involves a collection of nearly a million documents. In order to achieve useful results, the interaction of the human with the machine is central to the process.

The science - or perhaps the art - is to devise good means of picking out the relevant documents. Suppose a document is very long: should that be picked out more often than a short one on the same theme? Suppose a document contains a relevant word many times: should it be picked out more often than one which uses the word only infrequently? What does 'more often' mean, quantitatively speaking? The chosen answers to these questions give rise to decision rules which are implemented by the computer, using statistical weighting functions. With modern interactive computing, the user can change the decision rules to improve the search - narrowing, moving or widening its focus. Information Science thus reflects a wider view of human information-seeking activity as an active learning process.

7. Attitudes to Knowledge

By now, it will be obvious that the spiral games we have seen are not only metaphors for the growth of knowledge as it expands yet returns time and again to its objects of interest. These games are also frames of reference for the attitudes to knowledge in each of the four centuries surveyed by this lecture:

- for the seventeenth century, the original Game of Goose, typifying the Renaissance in facing back into arcane knowledge but forward into the beginnings of scientific modelling

- the Game of French Warriors, typifying the underlying use of symbolic representation of the world as it developed in the eighteenth century

- the Game of Genius and Invention, typifying the confidence and achievement of the nineteenth century.

Of course, these are greatly simplified views of a complex world of continually-shifting disciplines: an interesting lecture would be to explore what these views leave out! Examples of interest to Gresham College would be to study the division between Religion and Science; or the continuity of Mathematics, traceable from the Greek masters.

What game should we use to represent our present attitudes to knowledge?

I suggest that we have now moved so far from the certainties of previous centuries that only the underlying spiral is left. The metaphor of the spider's web is often used to describe in pictorial form the interconnected network of computers that now constitutes our world-wide knowledge store. If we ask, 'is it useful knowledge?' we receive the Delphic answers, 'to whom? and for what purposes?'. We may ask how this knowledge is structured and yet receive similarly unprescriptive answers. The reality is that the knowledge is not structured overall but there are local and partial structures around a web of points, not just in a two-dimensional array but in a hyperspace requiring many dimensions to display the full interconnectivity.

This has been characterised as a 'crisis of knowledge' in which the new information technologies are seen as destroying not only the traditional discipline-based organisation of knowledge but also many of the established academic and research structures of institutions themselves. Instead, there grow up continually-shifting 'virtual communities' on the internet, tenuously unified by some commonality of interest in a region of knowledge drawn with an indistinct boundary around some related points of the hyperspace.

Being ourselves part of this history, we find it difficult to obtain a perspective. Evidently, the technologies are in some sense ahead in development of the human systems which accompany them. The advance of knowledge by the scientific process requires the existence of communities of knowledge, groups of people who share a common paradigm and can therefore exchange information at a higher level of understanding than is possible in the general community. For the purposes of sharing research, the world-wide dialogue between experts is well mediated by the internet technologies. However, in this transitional stage, those experts have all been educated through routes which reflect a relatively traditional view of knowledge, both in its systematisation into disciplines and their embodiment in educational institutions. My own view is that those disciplines and those institutions will survive the present fashion for the deconstruction of knowledge; but disciplines are intrinsically more fluid than educational institutions and the tensions are becoming evident!

Looking back over 400 years to the time of Sir Thomas Gresham may enhance our ability to see these events in perspective and even to guide their future development.

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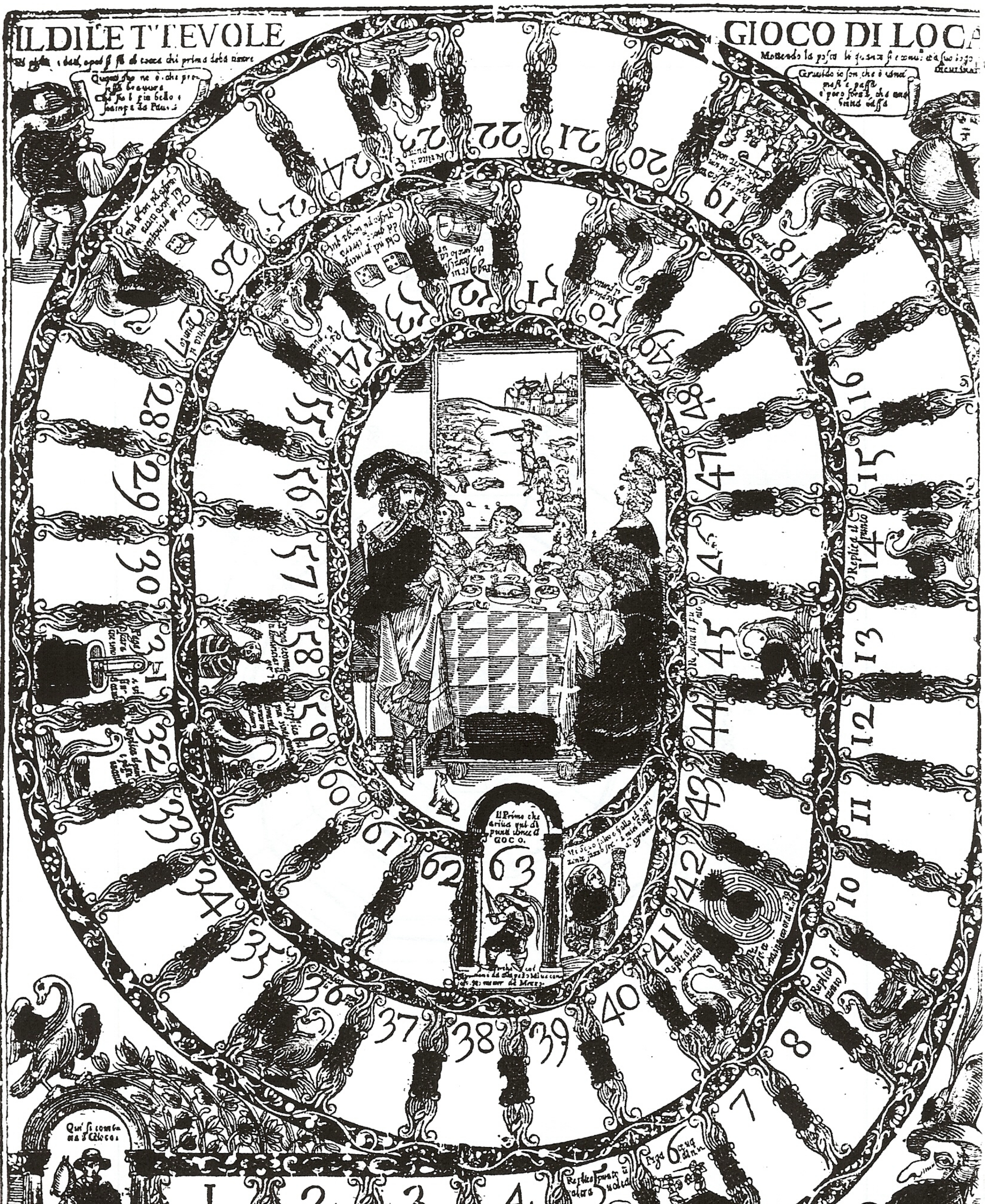
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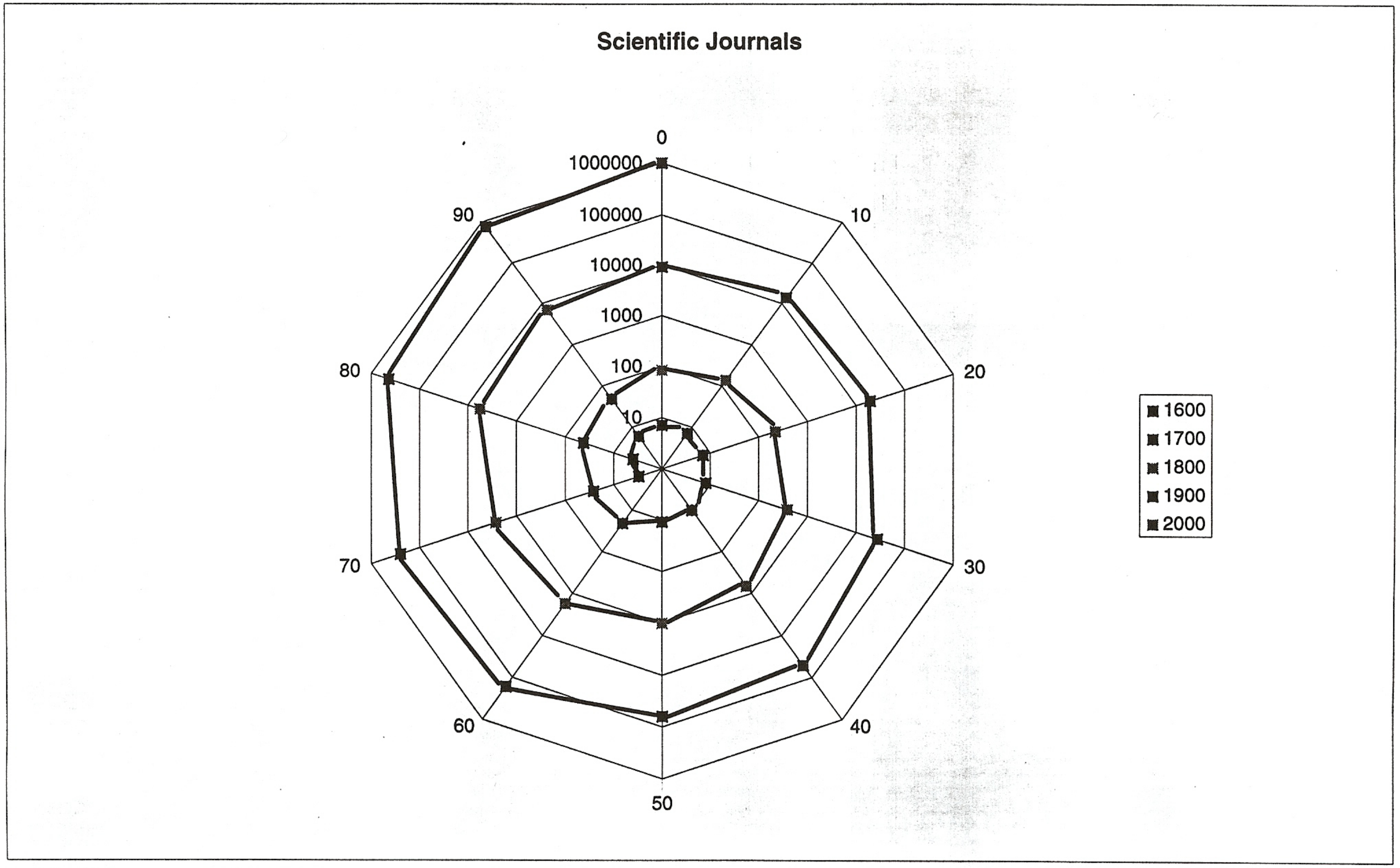
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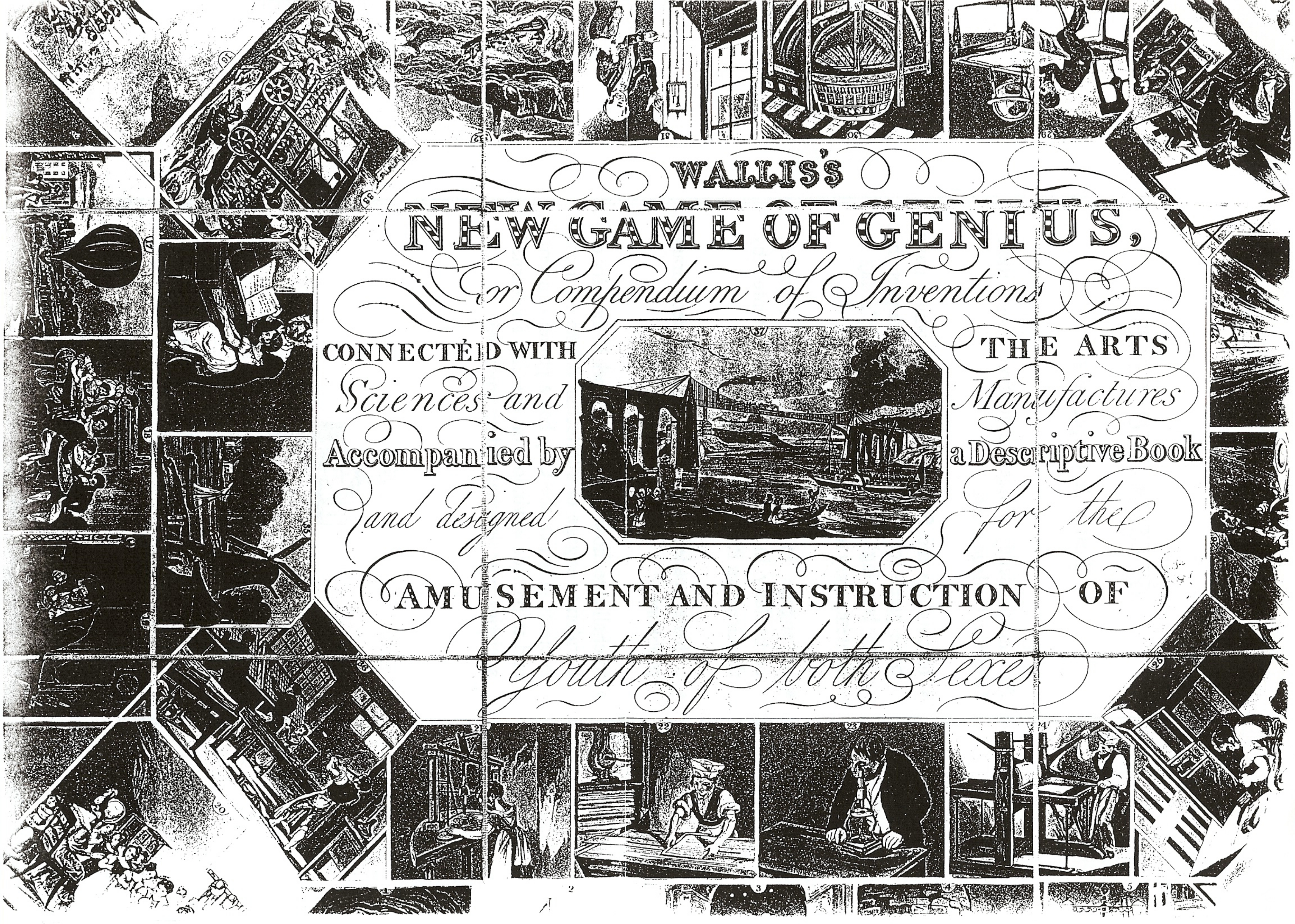
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GRESHAM COLLEGE

Policy & Objectives

An independently funded educational institution, Gresham College exists

- to continue the free public lectures which have been given for 400 years, and to reinterpret the 'new learning' of Sir Thomas Gresham's day in contemporary terms;

- to engage in study, teaching and research, particularly in those disciplines represented by the Gresham Professors;

- to foster academic consideration of contemporary problems;

- to challenge those who live or work in the City of London to engage in intellectual debate on those subjects in which the City has a proper concern; and to provide a window on the City for learned societies, both national and international.

Founded 1597

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