of the Brunauer-Emmett-Teller equation to the isotherms gave a monolayer capacity (N_m) of 2.35×10^{-7} mole g^{-1} and a Brunauer-Emmett-Teller constant (c) of 8.2. Using a cross-sectional area of $43.7 \text{ \AA}^2$ for the adsorbed benzene molecule¹, the calculated specific surface area of the beads was twenty-seven times the geometric area. The magnitude of the c value indicated that the pores were greater than $35 \text{ \AA}$ in diameter². Benzene adsorption on non-porous glass gave a specific surface area in agreement with the geometric area¹.

If it is assumed that the extent of porosity gives a measure of the degree to which the glass had been attacked (because all the beads had been subjected to the same weathering conditions), then all the beads had been attacked to the same extent. The appearance of the beads, therefore, was not related to the extent of attack. Because all the beads had been attacked to the same extent, it was expected that the clear and opaque fractions would have the same bulk chemical compositions, and this proved to be the case. Differences in appearances of the beads were therefore probably due to variations in the surface properties of the glass.

Ross and Roberts⁴ have shown that devitrification is a source of high specific surface areas in glass. The more opaque glass beads gave an electron diffraction pattern which was typical of saponite $[(Mg, Al, Fe)_2 (Al, Si)_4 O_{10} (OH)_2]$. This crystalline material, however, was only present in trace amounts, and its state of hydroxylation indicated that it was a product of weathering. The agreement between the isotherms suggested that the opaque products of weathering (which may have been partly crystalline) did not contribute significantly to the surface areas of these porous systems.

In conclusion, atmospheric water vapour may attack glass to form a porous surface layer. The appearance of the attacked glass is not necessarily related directly to the degree of attack, but may be correlated with a discrete surface property of the glass which may initiate or inhibit the formation of opaque products of weathering. Part of the products of weathering may be crystalline.

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GENERAL

Numerical Taxonomy and Textual Criticism of a Classical Latin Author

CRUDE forms of numerical tabulation were used as far back as the 1890s in efforts to determine genuineness or relative chronology of ancient writings, for example, by Lutoslawski¹ for the dialogues of Plato. The results were not without value when used in combination with other criteria, but an author's stylistic habits cannot be assumed to be constant throughout his period of literary activity, and much also turns on the investigator's subjective choice of *differentiae*.

Classification of manuscripts, an essential preliminary to any systematic textual criticism, is perhaps a more promising field for the more precise techniques now available. A manuscript tradition may be "pure bred", with successive generations of manuscripts directly copied from earlier exemplars; clerical errors and other indicative features will then be regularly distributed over the whole group of manuscripts. The interrelations of such a

monothetic (monotypic) array can be traced by routine methods and presented cladistically in the form of a family tree or *stemma*. Thus if half-a-dozen manuscripts all exhibit an identical dislocation (for example, the misplacing of the same block of lines by removal to the same place in the text), they are faithfully reproducing a feature of their common parent, and no particular problems arise.

When, however, readers or scholars in late antiquity (that is, before about A.D. 600) or in the Middle Ages (from 800 to about 1500) began to insert variant readings, either in the margins or between the lines with the desire to ease obscurities or otherwise to smooth the reader's progress, a complex situation arose. In these cases extant manuscripts show confused affiliations, which criss-cross in an apparently random fashion. Current doctrine in textual criticism treats these cases of "contaminated" or "horizontally interpolated" traditions as unamenable to systematic classification². Editors of such texts have therefore had to fall back on considerations of idiom and style when choosing between readings in doubtful places, rather than on a critical assessment of the credentials of the manuscripts offering the variants.

This may be a premature confession of defeat, however. Inspection shows that these patterns of manuscript interrelations have the characteristics of a polythetic (polytypic) array, where *differentiae* are no longer common to the whole group under investigation. In other disciplines taxonomic methods aided by computers have enabled research workers to take such problems in their stride. In the case of Juvenal, the Latin writer of verse satire (about A.D. 100), whose manuscripts have been collated in sufficient detail for the present purpose, the number of passages which exhibit significant variants is of the order of 1,500, too few to justify investigation using a computer programme. The number of manuscripts (the operational taxonomic units in this problem) varies between fourteen and sixteen, and warrants the use of computer methods although the actual calculations are laborious.

An analogy between the behaviour of the manuscript variants and that of mutant genes suggests itself: thus manuscript variants sometimes skip one or more generations, and something akin to chiasmatic arrangement appears on occasion. Although this resemblance should not be pressed, it offers a strategy of analysis for textual criticism. Coincidence of readings in blocks of more than 300 lines in two or more manuscripts can be plotted. Each block yields not less than 40–50 points of significant variation. Thus, using similarity matrices, I was able to establish a sequence of near-neighbour relations. This is not an order of merit; it is meaningless to speak of a "best" manuscript. It is, however, helpful to further investigation to know which manuscripts can be grouped together, especially where, as in the case of the Juvenal tradition, obvious but superficial differences obscure any underlying affinities. The groupings of manuscripts for successive stretches of the satires have been tested by Spearman's rank correlation coefficient and values of the order of $R = +0.8$ obtained, except in some instances where isolated manuscripts, which are suspect for other reasons, affect the calculation. With thirteen or fourteen degrees of freedom, such values of R yield a figure for Student's t greater than 0.1 per cent probability, that is, the odds against such consistent near-neighbour groupings being caused by mere chance are higher than a thousand to one.

Whether this taxonomic approach succeeds in penetrating to fundamental "genetic" affinities of the extant manuscripts of Juvenal is now open to debate, but I hope shortly to publish the data and reasoning in full.

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¹ Lutoslawski, W., *Origin and Growth of Plato's Logic* (London, 1897).

² Maas, P., *Textkritik* (English translation), 7 (Oxford, 1958).