

VOLUMETRIC COUNTS OF POLLEN GRAINS AT CARDIFF,  
1954-1957

H. A. HYDE, M.A. (CANTAB.), F.L.S., CARDIFF, WALES

INTRODUCTION

**T**HE *Hirst Automatic Volumetric Spore Trap (AVST)*.—It is generally agreed that allergic sensitivity to any particular kind of spore is usually acquired by inhaling it from the atmosphere and that both the diagnosis of allergic disease due to such inhalants and the assessment of the effects of its treatment demand a reasonably exact estimate of exposure. For all these reasons, allergists have long sought some means of obtaining a continuous record of the volumetric spore content of the atmosphere.

Scheppegrell<sup>27</sup> attempted, by applying Stokes's formula, to convert "gravity" slide figures directly into volumetric counts. His computations were corrected by Cocke.<sup>2</sup> Pollen grains are not, however, the smooth spheres which Stokes's formula presupposes. Dyakowska<sup>10</sup> found that pollen grains of different shapes but of approximately the same average diameter had widely different rates of fall. Dahl and Ellis,<sup>4</sup> for this and other reasons, deprecated the publication of volumetric computations unless they were accompanied by observed data expressed in terms of grains caught on unit area of exposed surface. Schmidt,<sup>26</sup> however, had pointed out many years earlier that, far from being still or in a state of streamlined motion, as Scheppegrell and others had presupposed, the outdoor air is in a constant state of turbulence; except for a very shallow layer close to the ground, "stokesian" conditions do not obtain outdoors,<sup>12</sup> and calculations based on the supposition that they do are fallacious. Cocke<sup>3</sup> devised and operated a volumetric apparatus and concluded from concurrent observations with gravity slides that his formula<sup>2</sup> for converting gravity slide counts into volumetric concentrations gave values which deviated up to 56 per cent from the actual concentrations obtaining. Durham<sup>5</sup> carried out similar calibration experiments with an impingement apparatus devised by Hawes and associates<sup>15</sup> and later, using the data so obtained as a "pivot," applied his own rate-of-fall figures<sup>6</sup> to compute volumetric estimates based on gravity slide counts.<sup>7</sup> Neither the forms of volumetric apparatus referred to, nor Hill's dust pump, also used by Durham,<sup>8</sup> seems to have been used to give average volumetric incidence over a whole season. Durham<sup>9</sup> later made computations with a view to expressing seasonal incidence in numerical terms, but they were not based on direct volumetric measurement. Gilbert<sup>11</sup> bubbled air at a measured

---

From the National Museum of Wales and the Asthma and Allergy Research Unit, St David's Hospital, Cardiff, Wales.

The substance of this article was included in a paper read before the British Association of Allergists at Liverpool, June 28, 1958.

Received for publication Oct. 31, 1958.

rate through a collecting solution to obtain estimates of volumetric incidence of ragweed and oak pollen grains at Columbus, Ohio, and compared simultaneous gravity slide counts.

A new approach to the volumetric estimation of airborne particles was made by May,<sup>25</sup> who utilized the principle that the numbers of airborne particles can be estimated ideally by means of a sampling tube, provided that the "orifice with a feathered leading edge faces upstream with suction applied at such a rate that the air velocities in the tube and the main air stream are equal." This principle—that of isokinetic sampling—was embodied by May in his "cascade impactor." In this apparatus a stream of air passes through a succession of sampling tubes and is impacted on a succession of fixed slides on which are caught particles of decreasing orders of size. The same principle was followed by Hirst<sup>16</sup> in his automatic volumetric spore trap, in which a single slide, coated with adhesive and mounted on a carrier actuated by clockwork, moves at the rate of 2 mm. an hour in front of a rectangular orifice measuring 14 by 2 mm. and therefore receives on its surface during twenty-four hours a band-shaped trace 14 mm. wide and 48 mm. long. The air flow is kept constant at 10 liters per minute, which corresponds with a wind speed of 6.0 meters per second or approximately 13.5 miles per hour. This slide is changed daily and, when scanned lengthwise, gives counts which correspond with the average volumetric content for the whole of the twenty-four hours. In theory, the counts made on scanning the slides should be corrected for the actual wind speed obtaining during the operation of the apparatus, and these corrections have been determined for two types of spore by actual calibration using a wind tunnel.<sup>1</sup> Since every type of spore would need its own table of corrections, however, it has been found more convenient to use the uncorrected figures, which in practice are known to be conservative.<sup>18</sup> The inventor of the apparatus has published volumetric counts of pollen grains (undifferentiated) and of various kinds of fungus spores obtained by short runs with his apparatus at Harpenden, England<sup>17</sup> and, in collaboration with Gregory, by a summer run also at Harpenden.<sup>13</sup> Gregory and Sreeramulu<sup>14</sup> have obtained similar series of observations in an estuarine area in southern England. Hamilton<sup>14a</sup> has reported on pollen and spore counts from London and Harpenden, Herefordshire, England.

*Operation of Hirst AVST at Cardiff.*—A Hirst trap was operated almost continuously from late April, 1954, until the end of the pollen season of 1957 at the pollen observatory on the roof of the National Museum of Wales, Cathays Park, Cardiff. The observatory is 60 feet above ground level, and the museum is situated at an altitude of 45 feet in an area which to the east and south is largely built up and for three miles to the north and west is suburban in character. The immediate neighborhood contains important sources of pollen, including grasses, weeds, and park trees. The country around Cardiff is mainly agricultural, with grass and arable fields and occasional scattered woods.<sup>20</sup>

Two small modifications of the procedure described by Hirst have been introduced. First, the adhesive employed was glycerin jelly (containing basic fuchsin as a stain) and not petrolatum. Second, the chain to which the slide carrier was originally attached was replaced by a steel violin E string, which was found less liable to accidental breakage.

The exposed slides have all been scanned lengthwise. From the counts thus obtained, the average daily volumetric incidence in grains per cubic meter has been computed. In all, eighty-nine types of pollen grains have been recognized,<sup>25</sup> and some 90 per cent of all grains observed have been determined.

#### RESULTS OF THE CENSUS

*Seasonal Incidence of Thirty Types.*—The principal results of scanning the daily slides, year by year, are summarized in Tables I to IV. It has been necessary, for the purpose of delimiting the season for each kind of pollen, to adopt an arbitrary end point; this value has been taken as one pollen grain per cubic meter (corresponding to two grains per 0.9 sq. cm. of adhesive surface on the daily slide). Seasonal incidence (P) of a particular pollen type

TABLE I. ATMOSPHERIC POLLEN AT CARDIFF, 1954 (APRIL 26 ONWARD)  
SEASONAL INCIDENCE OF TWENTY-ONE TYPES AS DETERMINED BY DAILY VOLUMETRIC COUNTS

| POLLEN TYPE                   | PERIOD            | DAYS<br>(n) | AVERAGE<br>VOLUMETRIC<br>COUNTS IN<br>GRAINS PER<br>CUBIC METER<br>(P) | SEASONAL<br>INCIDENCE<br>$P = n \times P$<br>(UNITS) |
|-------------------------------|-------------------|-------------|------------------------------------------------------------------------|------------------------------------------------------|
| Acer (sycamore, maple)        | April 29-May 6    | 8           | 1.5                                                                    | 12                                                   |
| Aesculus (horse chestnut)     | May 14-24         | 11          | 1.0                                                                    | 11                                                   |
| Artemisia (mugwort)           | August 4-28       | 25          | 1.0                                                                    | 25                                                   |
| Castanea (sweet chestnut)     | July 4-August 10  | 38          | 3.0                                                                    | 114                                                  |
| Chenopodiaceae (beet family)  |                   | 0           |                                                                        | 0                                                    |
| Compositae (excl. artemisia)  | May 19-July 7     | 50          | 0.5                                                                    | 25                                                   |
| Cyperaceae (sedge family)     | May 8-21          | 14          | 1.0                                                                    | 14                                                   |
| Ericaceae (heather family)    | August 31-Sept. 7 | 8           | 0.5                                                                    | 4                                                    |
| Fagus (beech)                 | May 12-15         | 4           | 1.5                                                                    | 6                                                    |
| Gramineae (grasses)           | May 3-Sept. 24    | 145         | 25.0                                                                   | 3,625                                                |
| Juncaceae (rush family)       | July 12-14        | 3           | 1.5                                                                    | 4.5                                                  |
| Pinus (pine)                  | May 15-June 15    | 32          | 5.0                                                                    | 160                                                  |
| Plantago (plantain)           | May 5-Sept. 6     | 125         | 2.0                                                                    | 250                                                  |
| Platanus (plane)              | May 8-23          | 16          | 1.0                                                                    | 16                                                   |
| Quercus (oak)                 | April 30-June 21  | 53          | 11.0                                                                   | 583                                                  |
| Ranunculus (buttercup)        | June 22           | 1           | 1.5                                                                    | 1.5                                                  |
| Rumex (sorrels and docks)     | May 26-August 4   | 71          | 2.0                                                                    | 142                                                  |
| Sambucus (elder)              | June 13-July 3    | 21          | 1.5                                                                    | 31.5                                                 |
| Tilia (linden)                | July 1-28         | 28          | 4.0                                                                    | 112                                                  |
| Umbelliferae (parsnip family) |                   | 0           |                                                                        | 0                                                    |
| Urtica (nettle)               | May 29-Sept. 18   | 113         | 20.0                                                                   | 2,260                                                |

*Note:* The following types are omitted from this table because in 1954 their respective pollen seasons were more or less complete before April 26: Alnus, Betula, Carpinus, Corylus, Fraxinus, Populus, Salix, Taxus, and Ulmus.

has been computed simply as the product  $n \times p$  where  $n$  equals number of days from first count of one grain per cubic meter to the last such count in the year concerned and  $p$  equals the average mean daily concentration during the season. Some kinds of pollen in certain seasons failed to register a mean

concentration of one grain per cubic meter on any single day; their seasonal incidence for the year(s) concerned has been entered as zero, notwithstanding the fact that grains of the type concerned may have been caught in our apparatus, although in numbers here regarded as negligible.

TABLE II. ATMOSPHERIC POLLEN AT CARDIFF, 1955  
SEASONAL INCIDENCE OF THIRTY TYPES AS DETERMINED BY DAILY VOLUMETRIC COUNTS

| POLLEN TYPE                   | PERIOD            | DAYS<br>(n) | AVERAGE<br>VOLUMETRIC<br>COUNTS IN<br>GRAINS PER<br>CUBIC METER<br>(P) | SEASONAL<br>INCIDENCE<br>$P = n \times P$<br>(UNITS) |
|-------------------------------|-------------------|-------------|------------------------------------------------------------------------|------------------------------------------------------|
| Acer (sycamore, maple)        | May 7-14          | 8           | 0.5                                                                    | 4                                                    |
| Aesculus (horse chestnut)     | May 12-30         | 19          | 0.5                                                                    | 9.5                                                  |
| Alnus (alder)                 | March 16-April 13 | 29          | 4.0                                                                    | 116                                                  |
| Artemisia (mugwort)           | July 27-August 23 | 28          | 2.0                                                                    | 56                                                   |
| Betula (birch)                | April 20-May 12   | 23          | 4.0                                                                    | 92                                                   |
| Carpinus (hornbeam)           |                   | 0           |                                                                        | 0                                                    |
| Castanea (sweet chestnut)     | July 10-August 12 | 34          | 3.0                                                                    | 102                                                  |
| Chenopodiaceae (beet family)  | July 23-August 27 | 36          | 2.0                                                                    | 72                                                   |
| Corylus (hazel)               | March 16-April 13 | 29          | 2.0                                                                    | 58                                                   |
| Compositae (excl. artemisia)  | June 5-August 27  | 84          | 0.5                                                                    | 42                                                   |
| Cyperaceae (sedge family)     | May 23-June 2     | 11          | 1.0                                                                    | 11                                                   |
| Ericaceae (heather family)    |                   | 0           |                                                                        | 0                                                    |
| Fagus (beech)                 |                   | 0           |                                                                        | 0                                                    |
| Fraxinus (ash)                | April 13-May 11   | 29          | 23.0                                                                   | 667                                                  |
| Gramineae (grasses)           | May 4-Sept. 8     | 128         | 77.0                                                                   | 9,856                                                |
| Juncaceae (rush family)       | June 30-August 7  | 39          | 1.0                                                                    | 39                                                   |
| Pinus (pine)                  | May 25-June 12    | 19          | 6.0                                                                    | 114                                                  |
| Plantago (plantain)           | May 21-Sept. 7    | 110         | 5.0                                                                    | 550                                                  |
| Platanus (plane)              | May 25            | 1           | 1.0                                                                    | 1                                                    |
| Populus (poplar)              | April 19-28       | 10          | 1.5                                                                    | 15                                                   |
| Quercus (oak)                 | May 9-June 6      | 29          | 4.0                                                                    | 116                                                  |
| Ranunculus (buttercup)        | May 25-July 9     | 46          | 1.0                                                                    | 46                                                   |
| Rumex (sorrels and docks)     | May 29-July 30    | 63          | 7.0                                                                    | 441                                                  |
| Salix (willow)                | April 5-May 11    | 37          | 1.0                                                                    | 37                                                   |
| Sambucus (elder)              | June 17-July 31   | 45          | 2.0                                                                    | 90                                                   |
| Taxus (yew)                   | March 15-April 24 | 41          | 2.5                                                                    | 102.5                                                |
| Tilia (linden)                | July 7-28         | 22          | 3.0                                                                    | 66                                                   |
| Ulmus (elm)                   | March 15-May 12   | 59          | 13.0                                                                   | 767                                                  |
| Umbelliferae (parsnip family) | May 30-June 11    | 13          | 0.5                                                                    | 6.5                                                  |
| Urtica (nettle)               | June 4-Sept. 15   | 104         | 41.0                                                                   | 4,264                                                |

In Table V the thirty types whose incidence is recorded in detail in Tables I to IV are arranged in descending order of average incidence during the four (or three) years concerned. A gravity slide census covering thirteen years at Cardiff and one to five years at twelve other stations in Great Britain gave very similar results,<sup>22</sup> except that certain types of pollen grain which, by reason of their small diameter, are caught less efficiently on horizontal slides than the average are now seen to stand higher in order of numerical importance than was formerly supposed; this applies to chestnut (*Castanea*) and, above all, to nettle (*Urtica*). The source plants of the eight types at the top of Table V may be regarded as the chief hay fever plants of Great Britain.

The range of seasonal incidence registered varies widely in all types. Thus, in *Urtica* (nettle), *Plantago* (plantain), *Taxus* (yew), and *Populus* (poplar) the highest value is about twice the lowest; in grasses it is three

TABLE III. ATMOSPHERIC POLLEN AT CARDIFF, 1956  
SEASONAL INCIDENCE OF THIRTY TYPES AS DETERMINED BY DAILY VOLUMETRIC COUNTS

| POLLEN TYPE                   | PERIOD            | DAYS<br>(n) | AVERAGE<br>VOLUMETRIC<br>COUNTS IN<br>GRAINS PER<br>CUBIC METER<br>(P) | SEASONAL<br>INCIDENCE<br>$P = n \times P$<br>(UNITS) |
|-------------------------------|-------------------|-------------|------------------------------------------------------------------------|------------------------------------------------------|
| Acer (sycamore, maple)        | May 6-23          | 18          | 1.0                                                                    | 18                                                   |
| Aesculus (horse chestnut)     | May 15-23         | 9           | 1.0                                                                    | 9                                                    |
| Alnus (alder)                 | March 4-April 14  | 42          | 8.0                                                                    | 336                                                  |
| Artemisia (mugwort)           | August 7-21       | 15          | 3.0                                                                    | 45                                                   |
| Betula (birch)                | April 11-May 26   | 46          | 38.0                                                                   | 1,748                                                |
| Carpinus (hornbeam)           | April 10-May 1    | 22          | 1.0                                                                    | 22                                                   |
| Castanea (sweet chestnut)     | July 8-August 15  | 39          | 9.0                                                                    | 351                                                  |
| Chenopodiaceae (beet family)  | July 24-August 13 | 21          | 1.0                                                                    | 21                                                   |
| Corylus (hazel)               | March 4-April 7   | 35          | 7.0                                                                    | 245                                                  |
| Compositae (excl. artemisia)  | June 13-July 19   | 37          | 0.2                                                                    | 7.5                                                  |
| Cyperaceae (sedge family)     | May 10-June 12    | 34          | 1.0                                                                    | 34                                                   |
| Ericaceae (heather family)    |                   | 0           |                                                                        | 0                                                    |
| Fagus (beech)                 | May 4-26          | 23          | 11.0                                                                   | 253                                                  |
| Fraxinus (ash)                | April 11-May 10   | 30          | 8.0                                                                    | 240                                                  |
| Gramineae (grasses)           | May 4-Sept. 26    | 146         | 28.0                                                                   | 4,088                                                |
| Juncaceae (rush family)       | May 1-16          | 16          | 0.5                                                                    | 8                                                    |
| Pinus (pine)                  | May 16-June 23    | 39          | 4.0                                                                    | 156                                                  |
| Plantago (plantain)           | May 10-Sept. 2    | 116         | 5.0                                                                    | 580                                                  |
| Platanus (plane)              | May 10-June 4     | 26          | 3.0                                                                    | 78                                                   |
| Populus (poplar)              | April 7-26        | 20          | 1.5                                                                    | 30                                                   |
| Quercus (oak)                 | May 7-June 22     | 47          | 17.0                                                                   | 799                                                  |
| Ranunculus (buttercup)        | May 29-June 11    | 14          | 0.5                                                                    | 7                                                    |
| Rumex (sorrels and docks)     | May 21-July 29    | 70          | 5.0                                                                    | 350                                                  |
| Salix (willow)                | March 27-May 10   | 45          | 2.5                                                                    | 112.5                                                |
| Sambucus (elder)              | June 12-July 30   | 49          | 1.0                                                                    | 49                                                   |
| Taxus (yew)                   | March 4-May 9     | 67          | 5.5                                                                    | 368.5                                                |
| Tilia (linden)                | June 28-July 29   | 32          | 3.0                                                                    | 96                                                   |
| Ulmus (elm)                   | March 4-May 15    | 73          | 30.0                                                                   | 2,190                                                |
| Umbelliferae (parsnip family) | June 1            | 1           | 1.5                                                                    | 1.5                                                  |
| Urtica (nettle)               | May 31-Sept. 27   | 120         | 19.0                                                                   | 2,280                                                |

times as high and in certain trees it is very much higher. Over a longer period of years, wider differences might well be observed. These variations are illustrated graphically in the frequency diagrams (Figs. 2 to 9) and especially by those for tree pollens (elm, ash, birch, and oak in Figs. 2, 3, 4, and 6, respectively). The potential significance to allergists of such variations has been indicated in an earlier communication<sup>23</sup>; it should always be borne in mind when the effects of treatment are assessed.

*Phenology:* The time relations of the various types are set out in the calendar (Fig. 1), in which are indicated the earliest and latest dates, respectively, in any of these four (or three) years on which a count of at least 1 grain per cubic meter was registered, and also the period, if any, during which such a minimum count was registered in each and all of these years. For example, elm pollen was present in 1957 as early as February 2 and in 1956 as late as mid-May, while every year it was present from March 15 to 30, as shown by the black line. Eighteen types out of the thirty exhibited such a *constant period*; three (grasses, plantain, and nettle) had very long ones, but twelve had none. The data here recorded are essentially similar to those obtained in earlier studies based on horizontal slides.<sup>19-21</sup>

*Day-to-day incidence with special reference to eight principal types:* The day-to-day volumetric counts of all types exhibit considerable oscillations during the course of each season, so that the average figures given in Tables I to V do not nearly state the actual mean daily concentrations to which patients may be subjected from time to time. Details of the atmospheric incidence of the eight principal types during the years 1954 (or 1955) to 1957 are therefore set out graphically in the form of day-to-day frequency diagrams in Figs. 2 to 9. The order is that of seasonal onset. The diagrams may be distinguished according to their general pattern as either compact (symmetrical about a midseason maximum) or diffuse (with no regularly recurring maximum phase).<sup>20</sup>

TABLE IV. ATMOSPHERIC POLLEN AT CARDIFF, 1957  
SEASONAL INCIDENCE OF THIRTY TYPES AS DETERMINED BY DAILY VOLUMETRIC COUNTS

| POLLEN TYPE                   | PERIOD                       | DAYS<br>(n) | AVERAGE<br>VOLUMETRIC<br>COUNT IN<br>GRAINS PER<br>CUBIC METER<br>(P) | SEASONAL<br>INCIDENCE<br>$P = n \times P$<br>(UNITS) |
|-------------------------------|------------------------------|-------------|-----------------------------------------------------------------------|------------------------------------------------------|
| Acer (sycamore, maple)        | May 15                       | 1           | 1.0                                                                   | 1                                                    |
| Aesculus (horse chestnut)     | April 19-May 15              | 27          | 1.0                                                                   | 27                                                   |
| Alnus (alder)                 | March 7-28                   | 22          | 1.0                                                                   | 22                                                   |
| Artemisia (mugwort)           | August 1-22                  | 22          | 4.0                                                                   | 88                                                   |
| Betula (birch)                | March 28-May 25              | 59          | 9.5                                                                   | 560.5                                                |
| Carpinus (hornbeam)           |                              | 0           |                                                                       | 0                                                    |
| Castanea (sweet chestnut)     | June 26-August 3             | 36          | 2.5                                                                   | 90                                                   |
| Chenopodiaceae (beet family)  | August 1-12                  | 12          | 1.5                                                                   | 18                                                   |
| Corylus (hazel)               | February 26-April 4          | 38          | 1.0                                                                   | 38                                                   |
| Compositae (excl. artemisia)  | May 19                       | 1           | 2.0                                                                   | 2                                                    |
| Cyperaceae (sedge family)     | June 4-20                    | 17          | 0.5                                                                   | 8.5                                                  |
| Ericaceae (heather family)    |                              | 0           |                                                                       | 0                                                    |
| Fagus (beech)                 |                              | 0           |                                                                       | 0                                                    |
| Fraxinus (ash)                | March 19-April 24            | 37          | 14.0                                                                  | 518                                                  |
| Gramineae (grasses)           | April 5-Sept. 26             | 175         | 50.0                                                                  | 8,750                                                |
| Juncaceae (rush family)       | May 3-4; June 20-<br>July 10 | 23          | 1.0                                                                   | 23                                                   |
| Pinus (pine)                  | May 10-June 15               | 37          | 3.0                                                                   | 111                                                  |
| Plantago (plantain)           | April 24-Sept. 23            | 153         | 3.5                                                                   | 535.5                                                |
| Platanus (plane)              | April 19-May 5               | 17          | 0.5                                                                   | 8.5                                                  |
| Populus (poplar)              | March 26-April 14            | 20          | 1.5                                                                   | 30                                                   |
| Quercus (oak)                 | April 16-May 19              | 34          | 12.0                                                                  | 408                                                  |
| Ranunculus (buttercup)        | May 22                       | 1           | 1.5                                                                   | 1.5                                                  |
| Rumex (sorrels and docks)     | May 21-July 10               | 51          | 5.0                                                                   | 255                                                  |
| Salix (willow)                | March 12-April 5             | 25          | 0.5                                                                   | 12.5                                                 |
| Sambucus (elder)              | June 4-29                    | 26          | 2.5                                                                   | 65                                                   |
| Taxus (yew)                   | Feb. 1-April 5               | 64          | 4.0                                                                   | 256                                                  |
| Tilia (linden)                | June 19-July 13              | 25          | 7.0                                                                   | 175                                                  |
| Ulmus (elm)                   | Feb. 1-March 30              | 58          | 7.5                                                                   | 435                                                  |
| Umbelliferae (parsnip family) |                              | 0           |                                                                       | 0                                                    |
| Urtica (nettle)               | June 4-Sept. 26              | 115         | 18.0                                                                  | 2,070                                                |

*Elm (Ulmus, Fig. 2).* The diagrams for the two years, 1955 and 1956, are clearly of the compact type, attaining their maxima very near the middle of the season in both years. The 1957 season was much less intense and did not conform so closely to the same pattern. The differences in dates of onset of the pollen season are to be related to weather during the preceding

TABLE V. ATMOSPHERIC POLLEN AT CARDIFF, 1954 TO 1957  
THIRTY MAIN TYPES ARRANGED IN DESCENDING ORDER OF NUMERICAL IMPORTANCE

| POLLEN TYPE                   | AVERAGE<br>SEASONAL<br>INCIDENCE<br>(UNITS) | RANGE OF<br>SEASONAL<br>INCIDENCE<br>(PER CENT OF<br>AVERAGE) | HIGHEST MEAN DAILY<br>(24-HOUR) CONCENTRATION |                    |
|-------------------------------|---------------------------------------------|---------------------------------------------------------------|-----------------------------------------------|--------------------|
|                               |                                             |                                                               | VALUE<br>(GRAINS PER<br>CUBIC METER)          | DATE               |
| Gramineae (grasses)           | 6,580                                       | 55-150                                                        | 594                                           | June 24, 1955      |
| Urtica (nettle)               | 2,718                                       | 76-157                                                        | 205                                           | Aug. 31, 1954      |
| Ulmus (elm)                   | 848                                         | 51-258                                                        | 251                                           | April 3, 1956      |
| Betula (birch)                | 800                                         | 12-218                                                        | 299                                           | April 27, 1956     |
| Plantago (plantain)           | 479                                         | 52-121                                                        | 29                                            | June 11, 1956      |
| Quercus (oak)                 | 476                                         | 24-168                                                        | 77                                            | May 22, 1956       |
| Fraxinus (ash)                | 475                                         | 51-141                                                        | 142                                           | March 29, 1957     |
| Rumex (sorrels and docks)     | 297                                         | 48-150                                                        | 50                                            | June 11, 1956      |
| Taxus (yew)                   | 242                                         | 43-106                                                        | 67                                            | March 23, 1956     |
| Castanea (sweet chestnut)     | 161                                         | 47-217                                                        | 35                                            | July 17, 1956      |
| Alnus (alder)                 | 158                                         | 14-213                                                        | 75                                            | March 19, 1956     |
| Pinus (pine)                  | 135                                         | 82-118                                                        | 39                                            | June 1, 1955       |
| Corylus (hazel)               | 114                                         | 33-215                                                        | 34                                            | March 19, 1956     |
| Tilia (linden)                | 112                                         | 59-156                                                        | 24                                            | June 20, 1957      |
| Fagus (beech)                 | 64                                          | 0-395                                                         | 23                                            | May 9, 1956        |
| Sambucus (elder)              | 59                                          | 54-153                                                        | 12                                            | July 9, 1955       |
| Salix (willow)                | 54                                          | 24-210                                                        | 13                                            | March 27, 1956     |
| Artemisia (mugwort)           | 53                                          | 47-166                                                        | 11                                            | Aug. 7, 1957       |
| Chenopodiaceae (beet family)  | 28                                          | 0-257                                                         | 7                                             | Aug. 10 & 12, 1955 |
| Platanus (plane)              | 26                                          | 4-300                                                         | 13                                            | May 14, 1956       |
| Populus (poplar)              | 25                                          | 60-120                                                        | 10                                            | April 5, 1957      |
| Compositae (excl. artemisia)  | 19                                          | 10-221                                                        | 8                                             | May 19, 1954       |
| Juncaceae (rush family)       | 19                                          | 24-205                                                        | 8                                             | July 8, 1955       |
| Cyperaceae (sedge family)     | 17                                          | 53-200                                                        | 5                                             | May 16, 1956       |
| Ranunculus (buttercup)        | 14                                          | 11-328                                                        | 5                                             | June 17, 1955      |
| Aesculus (horse chestnut)     | 14                                          | 64-193                                                        | 5                                             | May 12, 1957       |
| Acer (sycamore, maple)        | 9                                           | 11-200                                                        | 5                                             | May 3, 1954        |
| Carpinus (hornbeam)           | 7                                           | 0-300                                                         | 4                                             | April 23, 1956     |
| Umbelliferae (parsnip family) | 2                                           | 0-300                                                         | 2                                             | June 1, 1955       |
| Ericaceae (heather family)    | 1                                           | 0-400                                                         | 2                                             | Sept. 7, 1954      |

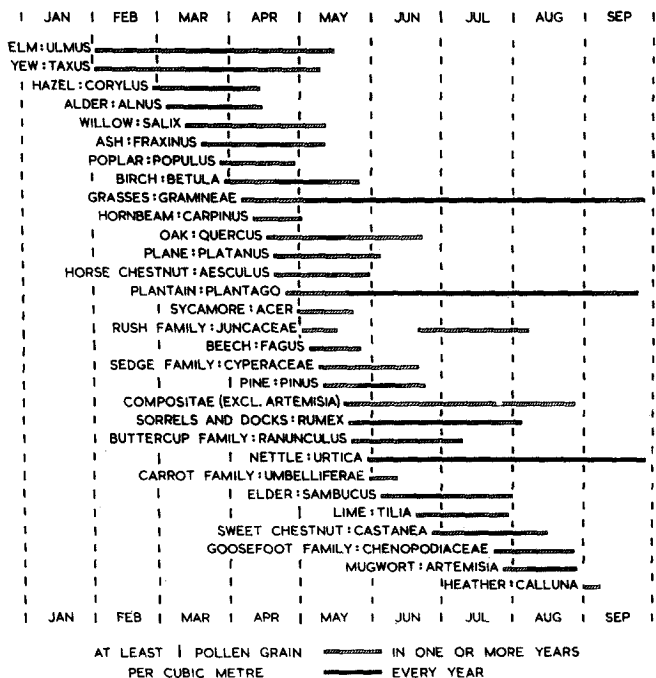


Fig. 1.—Atmospheric pollen calendar for Cardiff, based on direct volumetric counts, 1954-1957. (For further explanation, see text.)

months. The average mean temperature for January and February in 1955 and 1956 was  $36^{\circ}$  F., but in 1957 it was  $42.4^{\circ}$  F. The low daily and average concentrations observed in 1957 cannot be explained either by unfavorable weather (there were only three slight frosts after January 19) or by wind direction, which was prevailing westerly during the ulmus season in all three years; low pollen productivity in that year is doubtless to be related rather to the heavy fruiting observed in 1956 and the consequent exhaustion of reserves.

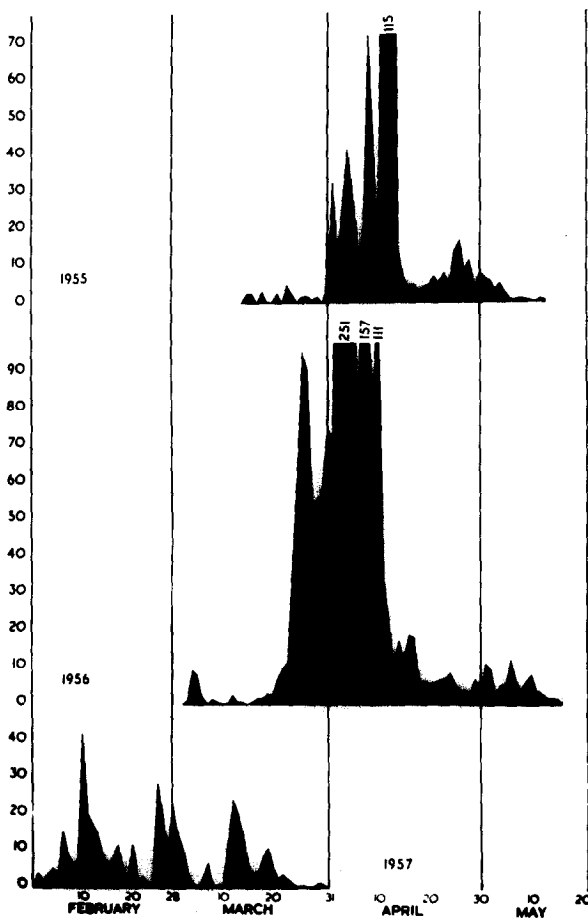


Fig. 2.—Elm (*Ulmus*) pollen at Cardiff, 1955-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

*Ash* (*Fraxinus*, Fig. 3). All the diagrams are compact, with the climax count at mid-season. The wide differences in date of onset and the reasons therefor are similar to those noted above for *Ulmus*. Here again, relatively low pollen productivity in one year (but not the same year) is to be related to internal causes and not to external influences.

*Birch* (*Betula*, Fig. 4). All the diagrams are compact. The contrasted seasons, 1955 and 1956, again illustrate the fact that in some trees a bumper

pollen season may follow or be followed by an almost negligible one. In each year except 1957 the highest concentration was recorded at mid-season.

*Grasses (Gramineae, Fig. 5).* Daily concentrations exhibit a pattern of rises and falls in which the rises increase up to a maximum before the middle of the season and thereafter decrease (compact type). The peak count

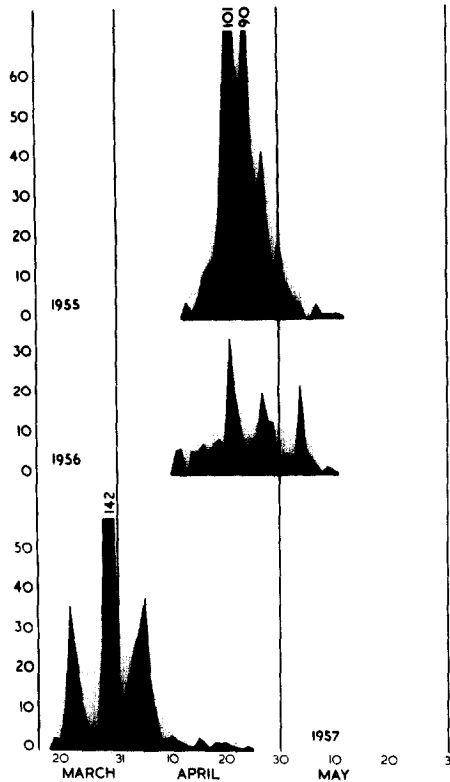


Fig. 3.—Ash (*Fraxinus*) pollen at Cardiff, 1955-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

always comes between the middle and the end of June—in 1954 on June 22, in 1955 on June 24, in 1956 on June 22, and in 1957 on June 15. Violent day-to-day oscillations in concentration are a normal feature of the grass pollen season in Great Britain; they seem to be related at Cardiff to oscillations in the daily number of hours of bright sunshine.<sup>21a</sup> In 1957, however, there was a period when both these sets of oscillations were suspended. From June 10 to July 6 the weather was unusually sunny; there was an average of 10.2 hours of bright sunshine daily. During this time the pollen count remained well up between 200 and 400 grains per cubic meter and over twenty-seven days averaged 282 per cubic meter. No such period of weather occurred at the same time of year in 1954, 1955, or 1956.

The 1957 grass pollen season also differed from the three preceding it in being virtually complete by July 10. The drought that had gone on

throughout June brought growth (and incidentally flowering) to a stop; rainfall from July 10 caused a resumption of growth but did not result in a recrudescence of grass-pollen fall (contrast with *Urtica*).

*Oak (Quercus, Fig. 6)*. The diagrams are compact. As in the case of *betula*, the pollen seasons of 1955 and 1956 form a marked contrast.

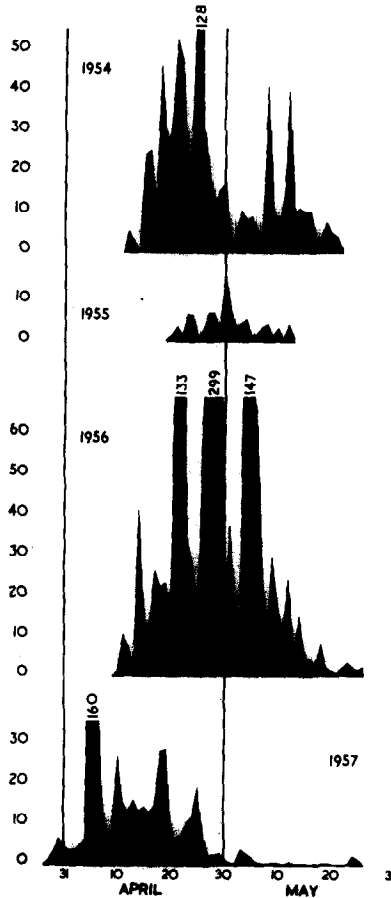


Fig. 4.—Birch (*Betula*) pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. Daily concentrations from April 12 to April 25, 1959, have been computed from gravity slide counts (the average relation between gravity slide and Hirst trap counts having been determined for *Betula* from concurrent exposures at Cardiff, 1955-1957). (For further explanation, see text.)

*Plantain (Plantago, Fig. 7)*. The frequency diagrams are of the diffuse type, although various submaxima occur. Pollen concentration was consistently lower throughout 1954 than in the subsequent years. The opening of the season varied widely, from May 20 in 1955 to April 24 in 1957.

*Rumex (sorrels, R. acetosa, and R. acetosella; and docks, especially R. crispus and R. obtusiflorus; Fig. 8)*. Pollen of *Rumex acetosa* is prevalent during June, that of the docks later, but no recurrent marked maxima can

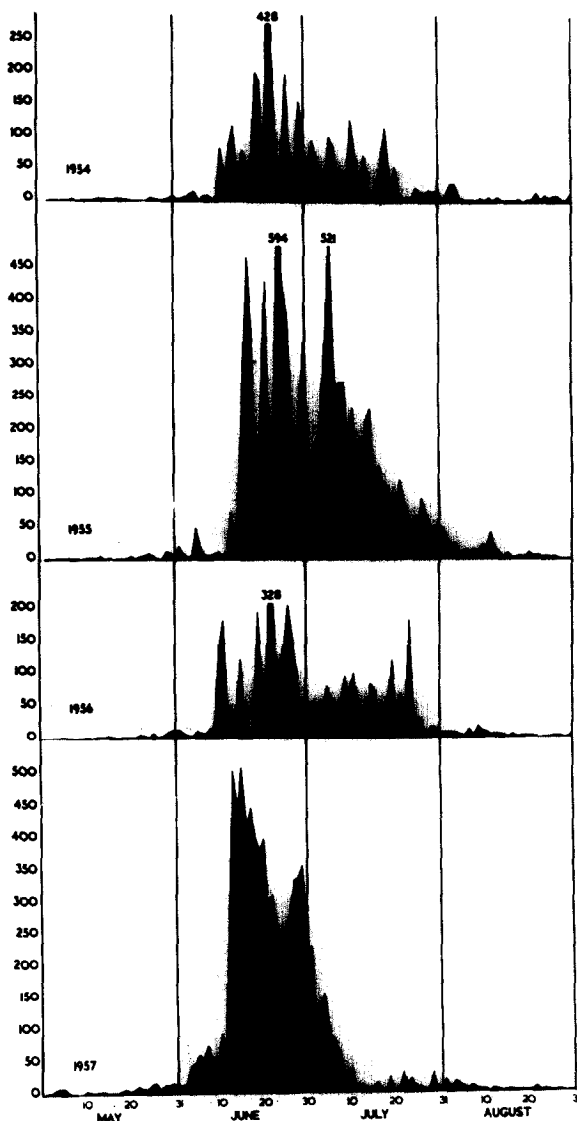


Fig. 5.—Grass pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. The effective onset of the season and the climax count both come in June every year; in other respects, the 1957 season differed from the three preceding seasons. (For further explanation, see text.)

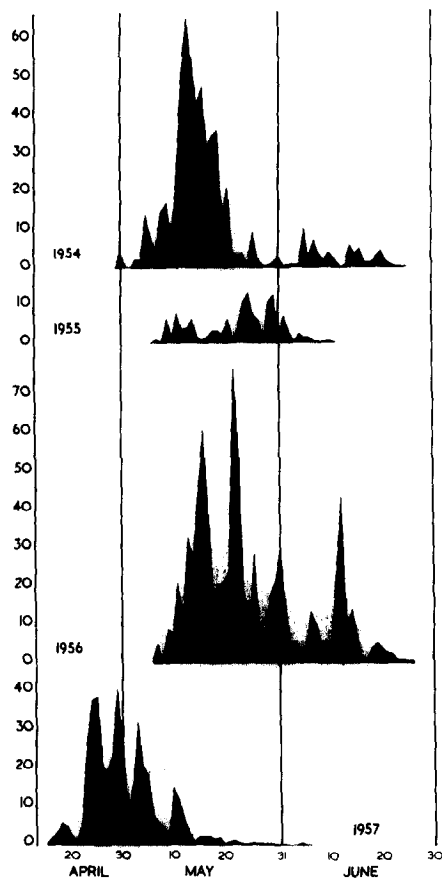


Fig. 6.—Oak (*Quercus*) pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

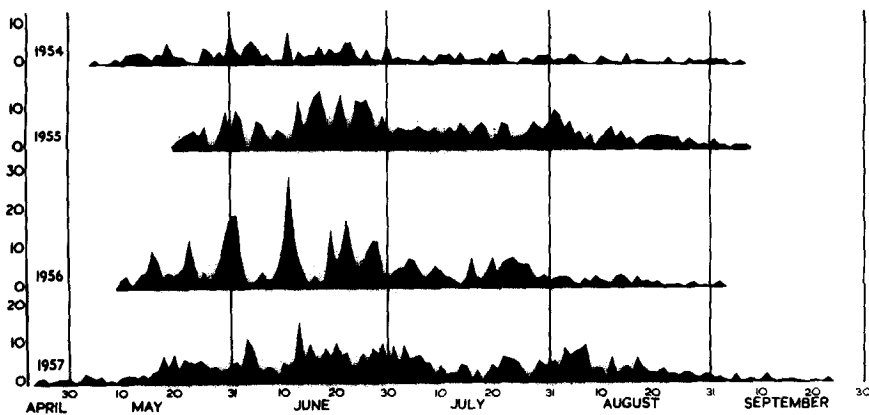


Fig. 7.—Plantain (*Plantago*) pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

be related to the seasons of the respective species. The diagrams are of the diffuse type, like those of plantago; here, too, average daily concentrations in 1954 are consistently low.

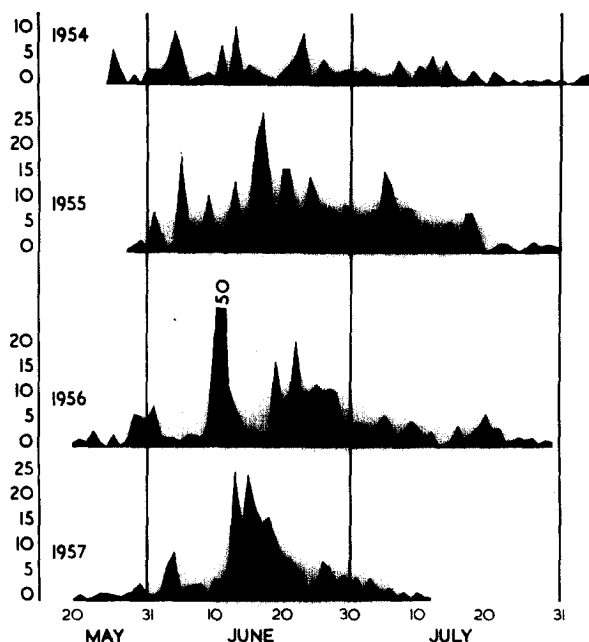


Fig. 8.—Sorrel and dock (*Rumex*) pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

*Nettle* (*Urtica*, Fig. 9). As already indicated by its position in Table V, nettle pollen is the only kind which during the period concerned gave volumetric counts comparable with those for grass pollen. The frequency diagrams differ from those for grasses in that there is no single peak period which recurs within a particular range of dates; the highest counts occurred in different years on various dates between June 16 and August 31. A preliminary consideration of these diagrams has shown that their general shape is related not to the calendar but to the weather, and in particular to pre-seasonal and coseasonal rainfall. Thus, the exceptionally dry period, from June 1 to July 6, 1957, followed a relatively dry spring; *Urtica* pollen release rose steeply after its onset to a moderate level on June 11 and thereafter fell steadily to a very low value on July 27. Rainfall in July permitted fresh growth and a new and higher wave of pollen production, the highest count of the season being attained on August 12 (contrast the grass pollen season for the same year).

The highest mean daily (twenty-four-hour) concentrations of all the thirty types whose incidence is here regarded as significant are stated in the fourth column of Table V.

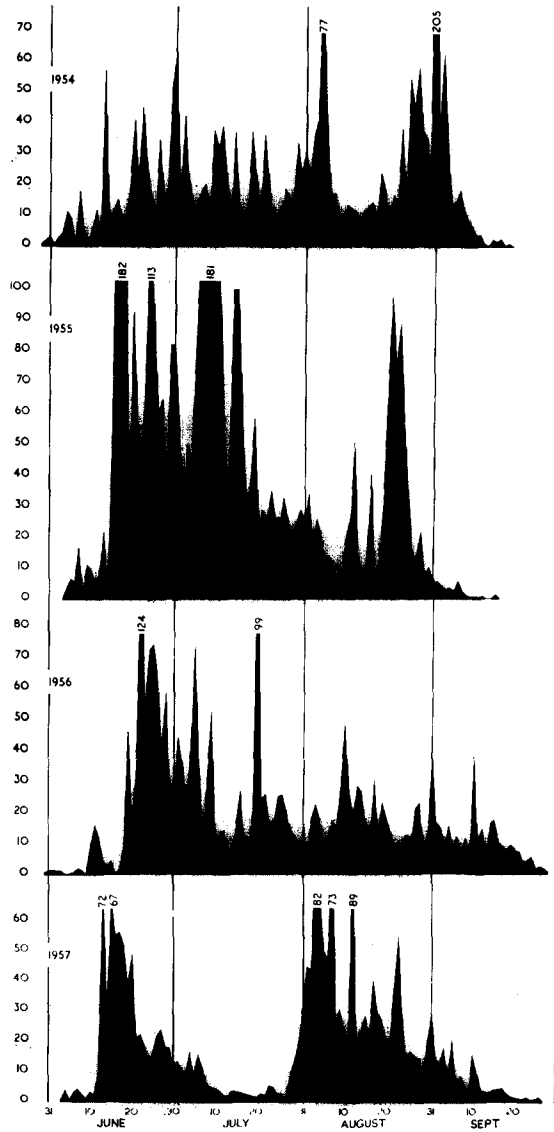


Fig. 9.—Nettle (*Urtica*) pollen at Cardiff, 1954-1957. Daily mean counts in grains per cubic meter. (For further explanation, see text.)

SUMMARY

1. The article presents the principal results of a four-year pollen census carried out with a Hirst automatic volumetric spore trap.

2. Direct volumetric estimates have been made of the pollen incidence of the various types of pollen concerned; the potential value of such estimates in the study of inhalant allergy needs no emphasis.

3. The survey has confirmed the general conclusions (based on a much longer gravity slide census) on the qualitative and (with the exceptions stated below) the quantitative botanical composition of the pollen cloud over South Wales, on the phenology and (with the same exceptions) the relative abundance of its constituent types, and on their variation from year to year.

4. Use of an efficient volumetric trap has made possible a more correct assessment of the numerical abundance of certain types (notably *Urtica*) whose relative importance, by reason of their small size, had previously been underestimated.

5. Attention is drawn to especially wide variations in the annual incidence of certain principal types and to the need to consider such variations when the effects of treatment are assessed.

Grateful acknowledgment is made to Dr. D. A. Williams, Medical Director of the Asthma and Allergy Research Unit, St. David's Hospital, Cardiff, for his unfailing interest and stimulating comment; to the technical staff of the Unit, particularly Mr. Morgan Robertson, Mrs. K. F. Adams, and Miss A. Gould, for their devoted work; and to the South Wales Electricity Board for use of a DC motor and to Mr. W. Hall for his ready help in connection therewith.

REFERENCES

1. Casella, C. F., & Co., Ltd., London: Hirst Spore Trap Instruction Leaflet (not dated).
2. Cocke, E. C.: Calculating the Pollen Concentration of the Air, *J. ALLERGY* 8: 601-606, 1937.
3. Cocke, E. C.: A Method for Determining Pollen Concentration, *J. ALLERGY* 9: 458, 1938.
4. Dahl, A. O., and Ellis, R. V.: The Pollen Concentration of the Atmosphere, *Pub. Health Rep.* 57: 369-377, 1942.
5. Durham, O. C.: Volumetric Incidence of Atmospheric Allergens. II. Simultaneous Measurements by Volumetric and Gravity Slide Methods, *J. ALLERGY* 15: 226-235, 1944.
6. Durham, O. C.: Volumetric Incidence of Atmospheric Allergens. III. Rate of Fall of Pollen Grains in Still Air, *J. ALLERGY* 17: 3-11, 1946.
7. Durham, O. C.: Volumetric Incidence of Atmospheric Allergens. IV. Proposed Standard Method of Gravity Slide Counting and Volumetric Interpolation of Results, *J. ALLERGY* 17: 79-86, 1946.
8. Durham, O. C.: Volumetric Incidence of Atmospheric Allergens. V. Spot Testing in the Evaluation of Species, *J. ALLERGY* 18: 231-238, 1947.
9. Durham, O. C.: Report of Pollen Survey Committee, American Academy of Allergy, 1949, *J. ALLERGY* 21: 442-454, 1950.
10. Dyakowska, J.: Researches on the Rapidity of the Falling Down of Pollen of Some Trees, *Bull. internat. Acad. polon. d. sc. et d. lett., Cl. méd.*, pp. 155-168, 1937.
11. Gilbert, G. E.: Gravity Slide Tests for Airborne Ragweed . . . at Columbus, Ohio, *Ohio J. Sc.* 50: 60-70, 1950.
12. Gregory, P. H.: The Dispersion of Airborne Spores, *Tr. Brit. Mycol. Soc.* 28: 26-72, 1945.
13. Gregory, P. H., and Hirst, J. M.: The Summer Air Spora at Rothamsted in 1952, *J. Gen. Microbiol.* 17: 135-152, 1957.
14. Gregory, P. H., and Sreeramulu, T.: Air Spora of an Estuary, *Tr. Brit. Mycol. Soc.* 41: 145-156, 1958.

- 14a. Hyde, H. A.: Grass Pollen in Great Britain, *Acta allergol.* 5: 98-112, 1952.
15. Hawes, R. C., Small, W. S., and Miller, H.: Apparatus for Determining Pollen Content of Air and Notes on Pollen Survey Methods, *J. ALLERGY* 13: 474, 1942.
16. Hirst, J. M.: An Automatic Volumetric Spore Trap, *Ann. appl. Biol.* 39: 257-265, 1952.
17. Hirst, J. M.: Changes in Atmospheric Spore Content; Diurnal Periodicity and the Effects of Weather, *Tr. Brit. Mycol. Soc.* 36: 375-393, 1953.
18. Hirst, J. M.: Personal communication, 1957.
19. Hyde, H. A.: Phenology of British Hay Fever Plants and Its Significance to Allergists, *Brit. M. J.* 1: 897, 1949.
20. Hyde, H. A.: Studies in Atmospheric Pollen. IV. Pollen Deposition in Great Britain, 1943. I. The Influence of Situation and Weather, *New Phytol.* 49: 398-406, 1950.
21. Hyde, H. A.: Studies in Atmospheric Pollen. IV. Pt. II. The Composition of the Pollen Catch, *New Phytol.* 49: 407-420, 1950.
- 21a. Hamilton, E.: Ph.D. Thesis, University of London, 1957.
22. Hyde, H. A.: A Census of Atmospheric Pollen and Its Possible Applications, *Proc. Linn. Soc., London* 165: 107-112, 1955.
23. Hyde, H. A.: Tree Pollen in Great Britain, *Acta Allergy* 10: 224-245, 1956.
24. Hyde, H. A., and Adams, K. F.: An Atlas of Airborne Pollen Grains, London, 1958, The Macmillan Company.
25. May, K. R.: The Cascade Impactor: an Instrument for Sampling Coarse Aerosols, *J. Sci. Instruments* 22: 187-195, 1945.
26. Schmidt, W.: Über die Verbreitung von Samen u. Blütenstaub, durch den Wind, *Oesterr. Bot. Ztschr.* 67: 313-328, 1918.
27. Scheppegegrell, W.: Hay Fever and Hay Fever Pollens, *Arch. Int. Med.* 19: 959-980, 1917.