by Cl-filled Geissler tubes, extend from 2300A in the ultra-violet to 9900A in the infra-red.

With the aid of these new lines and those in the extreme ultra-violet, published by Turner,[2] we have succeeded in working out the structure of the arc spectrum of chlorine, Cl I. In its unexcited state the outer electron configuration of the chlorine atom is s^2p^5 from which, according to Hund's theory,[3] we may expect the lowest term of the spectrum to be ^2P. This term and others arising from the various electron configurations assumed by the excited atom are based on the term ^3P of Cl II, which was established by Bowen.[4] In the following table are listed the theoretical terms to be expected, those already found in this investigation being printed in heavy type. Terms based on ^1D and ^1S of Cl II will produce only faint lines and are here omitted.

Electron Configuration	Doublet System Terms	Quartet System Terms
s^2p^5	**P**	
$s^2p^4 \cdot 3d$	F D P	F D P
$s^2p^4 \cdot 4s$	**P**	**P**
$s^2p^4 \cdot 4p$	**D P S**	**D P** S
$s^2p^4 \cdot 4d$	F D P	F D P
$s^2p^4 \cdot 5s$	P	P
$s^2p^4 \cdot 5p$	**D P S**	**D P** S

Turner's lines, already interpreted by Bowen[5] and by Laporte,[6] represent the combinations of the odd lowest ^2P term with the higher even terms ^2P and ^4P coming from the configuration $s^2p^4 \cdot 4s$. The new lines in the red and infra-red represent the combinations of ^2P and ^4P ($s^2p^4 \cdot 4s$) with the doublet and quartet, S, P, and D terms arising from $s^2p^4 \cdot 4p$. A still higher set of doublet and quartet, S, P, and D terms arising from $s^2p^4 \cdot 5p$ combines with the even terms ^2P and ^4P to give the arc lines in the blue and violet described by Asagoe[7] and beautifully illustrated in the map given by Eder and Valenta.[8]

It is thus seen that in structure Cl I closely parallels A II, recently worked out by De Bruin.[9] The ^2S and ^2P terms which arise when the activated electron is raised to the $4p$, $5p$, . . . orbits, form Rydberg series from which the value of the lowest term may be derived. This value turns out to be 106000 which agrees with the value 105000 found by interpolation from those for S I and A I. The ionization potential of the neutral chlorine atom is therefore 13.1 volts.

The details of the investigation will appear in an early number of the *Bureau of Standards Journal of Research*.

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2 Turner, *Physical Review*, 27: 402, 1926.

3 Hund, "Linienspektren und Periodisches System der Elemente," Berlin, 1927.

4 Bowen, *Physical Review*, 31: 34, 1928.

5 Bowen, *Physical Review*, 31: 498, 1928.

6 Laporte, *Nature*, 121: 1021, 1928.

7 Asagoe, *Mem. College of Science*, Kyoto, A 10: 15, 1926.

8 Eder and Valenta, "Beiträge zur Photochemie und Spectralanalyse," Vienna, 1904.

9 De Bruin, *Kon. Akad. Wet. Amsterdam*, 37: 553, 1928. *Zeitschrift für Physik*, 48: 62, 1928; and 50: 1928.

THE RELATION OF CERTAIN BACTERIA TO THE DEVELOPMENT OF ROOTS[1]

AN excessive localized development of small fibrous or fleshy roots has long been observed to occur on varying percentages of young apple trees in the nursery. Considerable doubt has attached both to the cause of this "hairy-root" condition and its effect upon the tree. The first important contribution to the knowledge of the etiology of this trouble was made by Smith and his coworkers[2] in their extensive researches on crowngall. They isolated from "hairy-root" malformations on young apple plants bacteria which they state "culturally and morphologically differ, if at all, only slightly from the crowngall organism." They report that five of eight young apple trees inoculated through punctures with these bacteria developed hairy-root symptoms, one developed galls and the other two remained free from malformations. Of four controls, none developed hairyroot, though one developed several galls. They do not report reisolation of the organism from hairyroot malformations on the inoculated plants or precautions to preclude the possibility that organisms from the soil may have played a part in inducing these hairyroot developments. However, they isolated from the inoculated tree which developed only galls an organism which, when plated, "looked typical for what was inserted." They state that this organism, when inoculated into healthy sugar beet, "produced both galls and hairy roots, indicating

1 Published with the approval of the director of the Wisconsin Agricultural Experiment Station. These studies were begun as a part of the Wisconsin program in the crowngall project supported cooperatively by the Crop Protection Institute, the Iowa State College of Agriculture and Mechanic Arts and the University of Wisconsin, and have been continued in cooperation with the United States Department of Agriculture.

2 E. F. Smith, Nellie A. Brown and C. O. Townsend, "Crowngall of Plants: its Cause and Remedy," U. S. Dept. Agr., Bur. Plant Indus. Bul. 213: 200, 1911.

that crown-gall and hairy-root are only two forms of the same disease." They worked more extensively with hairyroot and crowngall on other plants than apple. Among the isolations of bacteria which they studied, they recognized differences in pathogenicity and certain other characters, but preferred, on the basis of the evidence then at their command, to leave the species *Bacterium tumefaciens* Smith and Town. undivided.

Following the work just cited, the conception that hairyroot is caused by *Bact. tumefaciens* and is a phase of the crowngall disease became widely accepted.[3] The results of the present cooperative research, while in substantial accord with the experimental data published by Smith and his coworkers, furnish additional evidence which suggests that the etiology of the hairyroot condition is more complex than was earlier apparent.

Muncie[4] differentiated two types of abnormal root development on apple which he called "fibrous hairyroot" and "woolly knot." The former occurred quite commonly on apple seedlings, including lots grown from seeds which had been dipped for five minutes in mercuric chloride, 1–1,000, and planted in steamed soil. He concluded that this type is "probably noninfectious," and that the "'woolly knot' form is a manifestation of crowngall infection."

In previously reported studies of crowngall, callus and wound overgrowth on the crown and roots of grafted apple nursery stock, two of us[5] found that typical, highly pathogenic strains of *Bact. tumefaciens* were consistently isolated from galls which had been induced by inoculations with pure cultures of this organism and from galls of like appearance found on commercial nursery stock. From a large majority of the naturally occurring malformations that were studied, however, the technique used failed to isolate the typical, highly pathogenic crowngall organism. From many of these malformations which failed to yield the virulent crowngall bacteria, were isolated organisms which were similar to *Bact. tumefaciens* in certain routine diagnostic characters, but which failed to induce positive evidences of infection when inoculated through punctures into stems of tomato, tobacco, Pelargonium or apple. Establishment of the identity of these organisms and an interpretation of their relations to the plants with which they are associated was left to await further investigation. A brief report of progress on studies of these problems follows.

Many strains of bacteria which closely resemble *Bact. tumefaciens* on certain agar media, but which failed to cause infection when inoculated into tomato stems, were isolated from certain malformations on underground parts of grafted apple nursery trees. In numerous series of experiments they were inoculated by punctures into underground parts of one- or two-year-old grafted apple trees of the Wealthy variety. At the end of the growing season no typical crowngall or hairyroot was observed. However, in certain cases small enlargements or sparse root developments occurred at the places of inoculation. In later experiments, conducted in the spring and summer of 1927, similar inoculations were made into underground parts of the current year's shoots from the scions of newly set grafts as they developed in the nursery row. After a minimal incubation period of approximately six weeks, fleshy roots were found at the places of inoculation. They occurred singly or in groups and usually arose from slight enlargements. No root development or other malformation occurred about the punctures on control plants. In repetitions of this experiment in the field and in the greenhouse fifteen strains (isolations from fifteen sources) of bacteria of this type have been inoculated into young shoots of apple. Every strain stimulated root development. Control punctures gave uniformly negative results. The enlargements which occurred at the bases of these excessive root developments yielded cultures which, in each case, appeared on agar plates to be typical of the culture from which the inoculation had been made. Reinoculations have been made with each of the strains reisolated. As yet, results are available from but three of these. In each case the typical root stimulation occurred, while controls developed no malformations. In connection with these experiments similar inoculations were made from cultures of typical highly pathogenic *Bact. tumefaciens*. In every case typical crowngall developed. In no instance was any evidence of root stimulation observed. Controls developed no malformations.

Five of these root-stimulating cultures which were isolated from apple have been inoculated by punctures into underground parts of young shoots of honeysuckle (*Lonicera morrowii* Gray) and rose (*Rosa setigera* Michx.). On both honeysuckle and rose, each strain stimulated root development in a striking manner. In all cases control punctures gave negative results.

All the experiments on honeysuckle and rose and a portion of those on apple were performed in the greenhouse in steamed soil and under conditions de-

[3] A more complete review of literature will appear in a later paper.

[4] J. H. Muncie, "A Study of Crowngall Caused by *Pseudomonas tumefaciens* on Rosaceous Hosts," *Ia. State Coll. Jour. Sci.* 1: 57–110, 1926.

[5] A. J. Riker and G. W. Keitt, "Studies of Crowngall and Wound Overgrowth on Apple Nursery Stock," *Phytopath.* 16: 765–808, 1926.

signed to preclude chance intervention of *Bact. tumefaciens* or any similar organism.[6]

Bacteriological studies are being made of a series of these root-stimulating organisms in comparison with various soil organisms and *Bact. tumefaciens* isolated from typical crowngalls on apple. Although this work is incomplete, the data available have already established certain important differences between the root-stimulating cultures and the typical, gall-inducing *Bact. tumefaciens* of Smith and Townsend. These differences relate both to physiology and pathogenicity and are probably of specific rank.

The results thus far obtained give promise of elucidating at least one phase of the hairyroot question. At the same time they seem to open problems of much potential scientific and practical interest. What is the nature of the relationship of these root-stimulating organisms to the plants with which they are associated? Is it harmful or beneficial to the plant? If harmful, may these organisms be controlled economically; if beneficial, may they be adapted to use in plant culture to facilitate root development?

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THE MECHANISM OF PELLET FORMATION IN THE GREAT HORNED OWL (BUBO VIRGINIANUS)[1]

IT is well known that many birds, at varying intervals after feeding, regurgitate pellets composed of bones, fur, feathers and other indigestible materials, compactly arranged and free from digestible constituents as shown by the absence of any evidence of decomposition even after several days. The detailed report by B. P. Reed[2] on the formation of these pellets in the great horned owl suggested the use of this species as experimental subjects in an attempt to gain some information on the mechanism involved in delaying the passage of certain food materials through the stomach as occurring in higher forms. Of all the common birds displaying this phenomenon the owl forms the largest pellets and so seemed best adapted to the purpose.

Seven nestlings were secured at about the age of four weeks and raised in captivity so that they might become accustomed to handling. All but one became fairly tractable when properly handled. None was submitted to any experimental procedure until about six months old, at which time they had attained adult development.

One method of study was by fluoroscopic examination after ingestion of barium paste or of food mixed with paste. In the latter procedure freshly killed rats or guinea-pigs were cut into pieces and these rolled in thick paste, or raw liver was similarly treated; in other experiments finely minced meat, containing bones, hair or feathers, was mixed with barium paste and enclosed in small gauze bags and a definite number of these swallowed by the bird. It was then possible to count and locate these under the fluoroscope. These bags were invariably regurgitated as pellets entirely freed from digestible material in from twelve to twenty hours, the normal range of time involved in this process.

Another procedure involved aspiration of gastric juice at various stages of digestion. Usually not more than one or two cubic centimeters of fluid could be obtained, indicating that gastric secretion is not profuse at any time in this species. This material was tested for free and total acidity and peptic activity. All samples were highly viscid, dark in color, malodorous but never putrid.

Freshly regurgitated pellets were extracted with a measured quantity of water, squeezed dry and the extract filtered and tested as above, acidity being calculated for the original moisture content. These contained from two to three cubic centimeters of juice.

Two birds were killed at different stages of digestion of a meal consisting of the chopped body of a freshly killed rat, and the stomach contents examined both grossly and chemically.

Two trials at the preparation of gastric fistulae failed, but a third was successful, the bird continuing in a healthy state for several months and was finally killed for examination. But at no time was it possible to obtain enough gastric juice from the fistula for examination during digestion. Only a few drops were ever observed to escape from the opening at any time. This is a further indication that gastric secretion is not profuse in this species.

Post-mortem examination showed the pyloric opening of the stomach to be only about 1 mm in diameter, and in the normal position under the fluoroscope it was always found to lie on a level with the opening of the esophagus, so that practically the entire content

[6] On May 3, 1928, when the present paper was being prepared for publication, the writers were pleased to learn through correspondence that Miss Nellie A. Brown, of the Bureau of Plant Industry of the United States Department of Agriculture, in unpublished work, has induced the development of hairyroot on Paris-daisy plants which were inoculated with bacteria isolated from hairyroot on apple.

[1] From the Hull Physiological Laboratories, University of Chicago, and the Department of Physiology, Baylor Medical School.

[2] B. P. Reed, 1925, *The Auk*, xlii, 14.