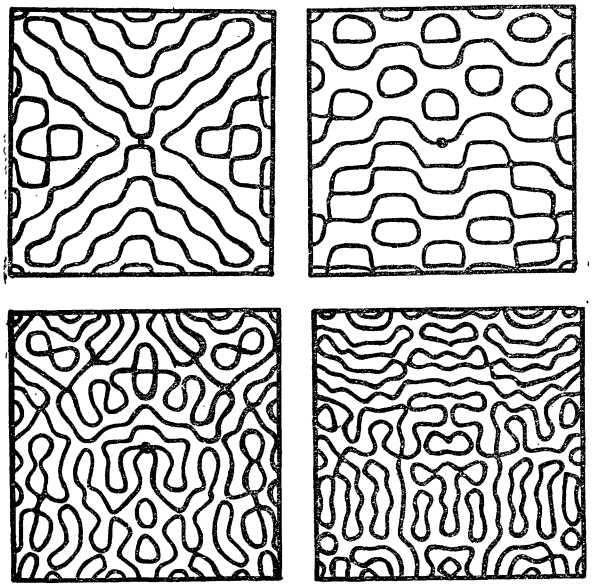
an amplifier or an oscillator, depending upon the circuit in which it is connected. As an oscillator, it will give out vibrations varying from several a second to millions a second. The lower or audible vibrations of a triode valve are produced by connecting the valve with a large inductance and capacity. Several years ago, it occurred to the writer that a valve oscillator



might be used to vibrate Chladni plates and so produce sand figures which had not been found before. The triode valve is connected in a circuit so as to produce audible notes from four to twelve kilocycles per second; both the inductance and the capacity are variable. The note from this circuit is passed into a power amplifier and thence into a telephone receiver or an electrodynamic loud speaker. One type of the complete set-up is illustrated in another article to which the reader is referred.[1] The vibrating member of the loud speaker is mechanically coupled to the Chladni plate by a small metal rod, one end of which is rigidly attached to the center of the vibrating diaphragm, while the other end is pressed against the underside of the Chladni plate. This connection corresponds to "loose coupling" in radio circuits. Sand is strewn upon the plate and the note changed by means of the variable condenser; when a suitable note is reached, the plate oscillates vigorously and nodal lines are formed. With this instrument, thin plates may be vibrated at high frequencies, thus producing extremely complicated but regular patterns. A few of these are shown in the figure. Andrade and Smith have used a similar device for the same purpose, but their coupling is magnetic and not mechanical.[2] Their method requires an electromagnet in place of the loud speaker and is applicable immediately to steel plates (or any other magnetic material). It would be necessary to attach a small steel button to a brass plate before the magnetic field could set it in vibration. Either method is an improvement on the violin bow.

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[1] *Phil. Mag.*, Vol. XII. Suppl., Aug., 1931, p. 320. See also *Jour. Franklin Inst.*, Aug., 1932, p. 199.

[2] Andrade and Smith, *Proc. Phy. Soc.*, 43, pp. 405–411, July, 1931.

SPECIAL ARTICLES

THE ARSENIC FUNGI OF GOSIO[1]

REFERENCES to poisoning in some way attributable to arsenic in coloring substances used upon wall paper, hangings or in carpets, or as a component of certain paints, began to appear about 1815. In the later years of the nineteenth century, such poisoning began to be correlated with the presence of arsenical gases such as arsine and with moldy conditions in the buildings in which the cases occurred. Then Gosio,[2] in 1892, demonstrated in laboratory experiments that certain fungi called by him the "arsenic fungi," were capable of setting such gases free, by their action upon compounds of arsenic.

The biochemical experiments of Gosio were accepted generally as showing that at least part of these poisoning cases were due to arsine or some other volatile compound of arsenic, produced by moldy areas in the rooms occupied by those injured. The exact nature of the gases produced seems still to be debatable and is under investigation by the insecticide division of this bureau. Maasen[3] restudied the biochemistry of Gosio's organism, *Penicillium brevicaule*, and drew distinctions between the gases produced by its activity upon arsenic, selenium and tellurium. By 1914, the number of studies had so increased that Huss included fifty-five titles in his bibliographic survey. Since that time comparatively few studies of this kind have been reported, and apparently very few

[1] This article is No. 1027 of the outside publication series of the Bureau of Chemistry and Soils.

[2] B. Gosio, "Azione di alcune muffe sui composti fissi d'arsenico," in *Rivista d'Igiene e Sanita Pubblica III*, (8/9): 201–230 and 261–273, 1892.

[3] Albert Maasen, "Die biologische Methode Gosio's zum Nachweis des Arsens und die Bildung organischer arsen-, Selen-, und Tellurverbindungen durch schimmelpilze und Bakterien," *Arbeiten aus dem Kaiserlichen Gesundheitsamte*, 18 (1): 475–489, 1902.

cases of poisoning from this source have been recognized.

Recently (*The Analyst,* March, 1932) Lerrigo[4] in England has reported two deaths attributed to arsenic, which was found by analysis of the body tissues. Epidemiological studies disclosed that the room in which the cases developed had moldy walls, which, when removed and analyzed, contained considerable quantities of arsenic. Arsenical odors were reported. Further proof of cause of death was not offered. This report lead Dr. C. A. Browne, assistant chief of the Bureau of Chemistry and Soils, to call our attention to the lack of published surveys of the so-called arsenic fungi in America and of their possibilities of harm.

It was a simple matter to inoculate arsenic-containing media with *Penicillium brevicaule* from our own culture collection and demonstrate the production of ill-smelling arsenical gases. Undertaking to follow this series of reactions to the field and to test their significance in America led to experiments in two directions: (1) Survey testing of stock cultures of molds whose habit and significance were already known, and (2) studies of the effect of arsenical dusts and sprays upon the microflora of the soil.

(1) For the survey tests 0.1 and 0.15 per cent. of arsenic, calculated as arsenious oxide, were added to Czapek's solution agar. In these cultures fifteen species of Penicillium proved negative (as had those reported by Huss[5]), with the possible exception of a feeble reaction from *P. duclauxi* Delacr. Twenty-two strains of Aspergillus, representing the taxonomic groups established by Thom and Church, furnished two active species, *A. fischeri* Wehmer and *A. sydowi* Bainier and Sartory, with only traces of arsenical gas from *A. fumigatus,* one of the *A. glaucus* group, and two of the *A. ochraceus* group. Our strains of the other genera reported positive by Huss and Gosio proved negative. In subsequent cultures ten strains or species of Scopulariopsis (the *P. brevicaule* series of older authors) were all active gas producers. Fourteen strains of *Aspergillus sydowi* were positive. Species of both of these groups are common in soil and in many other substances. Many of the organisms tested refused to grow at the arsenic concentration used and will be tested at lower concentrations later, hence some of the organisms, thus far found negative, may be in fact gas producers.

A number of other common aggregates, such as *Penicillium expansum, P. chrysogenum, P. roqueforti* and their allies, *Aspergillus flavus, A. oryzae* and the whole cosmopolitan group to which they belong, one species of Helminthosporium and an occasional Mucor grew well upon the arsenical substrata without producing ill-smelling gas. These may be called arsenic tolerant.

(2) For soil studies, Mr. W. B. Albert, of Florence, South Carolina, furnished samples of *Durham coarse sandy loam,* from the plots already discussed by Paden and Albert[6] as containing enough arsenic to prevent normal growth of certain crops. Mass cultures were first made to get a survey of the species of mold present. The Scopulariopsis or *P. brevicaule* group of species was not represented. A few colonies of green Penicillia and one or two colonies of Aspergillus developed. About two species of Fusarium and two or three sterile forms producing brown to black masses of mycelium, were the most abundant molds. Many colonies of Actinomyces were seen. Colonies of bacteria grew freely. Myamoebae and eventually one plasmodium developed upon mannite agar. No infusoria and no nematodes were seen.

Dilution cultures from the same soil upon arsenic agar (Czapek's solution agar with arsenic), showed the same species. Arsenical gas was detectable in all the petri dishes. Two strains of Fusarium, at least one sterile brown fungus, and one strain of Paecilomyces, when isolated and tested separately, were active gas producers. *Aspergillus ustus,* the Penicillia and some of the brown forms present were negative. The Actinomycetes and bacteria present have not yet been studied.

The species active do not appear, either from the literature (Gosio, Maasen, Huss and others) or from our experiments, to be exacting as to the form of arsenic compound presented. Some commercial "arsenicals" and some commercial products to which arsenic compounds have been applied as preservatives have been tested and found positive. These results agree with Huss' statement that some at least of these fungi will evolve arsenical gas from any arsenic compound presented.

The use of arsenical preservatives for manufactured products, particularly forest products, has been commercially developed and reported (Curtin)[7] to be effective for certain trade purposes. This literature has been reviewed only far enough to show that the possibilities of activity on the part of the "arsenic fungi," with the attendant production of noxious gases, are not discussed by them. Our own prelimi-

4 A. F. Lerrigo, "The Biological Method for the Detection of Arsenic," *The Analyst,* 57 (672): 155–158 and 163–4, 1932.

5 H. Huss, "Zur Kenntnis der biologischen Zersetzung von Arsenverbindungen, *Ztsch. f. Kyg. u. Infektionskrankheiten,* 76 (3): 361–406, 1914.

6 W. R. Albert and W. R. Paden, "Calcium Arsenate and Unproductiveness in Certain Soils," SCIENCE, 73 (1901): 622, 1931.

7 Leo Patrick Curtin, "Experiments in Wood Preservation. II—Arsenites of Copper and Zinc," *Ind. Engr. Chem.,* 19 (9): 993, 1927.

nary experiments indicate that the "arsenic fungi" will readily attack some of the arsenites used.

Certain conclusions are indicated:

(1) Arsenic fungi are more numerous than was previously supposed. Some saprophytic species common in the soil are active in the production of arsenical gases.

(2) Arsenic tolerant forms include many species which do not decompose arsenic compounds with the evolution of gases.

(3) Arsenical substances carried to the soil come in contact with decomposing agents, which tend to break them into volatile or quickly soluble forms. Accumulation of arsenic in the soil may be expected to occur only when massive amounts are used or under special conditions unfavorable to the development of a varied microflora.

(4) The disintegration of arsenical compounds may be caused by a considerable variety of fungi. Presumably, therefore, it is of sufficiently common occurrence to warrant the avoidance of arsenical preservatives for materials to be utilized in enclosed areas.

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WORK OUTPUT OF RATS SUBJECTED TO CONTINUOUS FARADIC STIMULATION

IN a preliminary study of work output in intact, anesthetized animals, using methods described below, it is possible to produce periodical muscular contractions for long periods of time.

Previous studies on rats and other animals have been supposed to demonstrate that skeletal muscle can be completely fatigued in a relatively short time. By the use of modified methods, however, in which the gastrocnemius muscle is subjected to faradic stimulation, it is possible to maintain a high level of work output for upwards of ten days, during which time the muscle lifts a 100-gram weight at the rate of three times per second. At the end of this time it is necessary to suspend experimentation because of complicating factors, such as general emaciation, edema, infection and other conditions of the muscle.

Although some decrease in output is noted throughout the work period it is believed that the complicating factors mentioned above are in large measure responsible for the more pronounced decrease observed near the end of the experimental period. At no time, however, does the working muscle show signs of complete fatigue. On the contrary, a fair level of output is maintained up to the time the animals are removed.

The total amount of work, as calculated for each animal by the aid of an automatic recording device, is found to range between 105,000,000 and 177,000,000 ergs. This is only a rough approximation, however, since such factors as friction and inertia have not been allowed for in making the calculation.

In so far as the writers have been able to determine, both the time and work records obtained are considerably greater than any previously reported. It is believed that this greater amount of work is due primarily to differences in method employed. In trying various methods it was found, for example, that activation of the muscle by stimulating the peripheral portion of the severed sciatic nerve was accompanied by dying of the nerve, a rapid loss in muscle irritability and consequently a shortened work period. This shortened work period or supposed "fatigue" proved therefore to be an artifact of the dying of the nerve and did not give a true picture of the muscles' capacity for energy output.

It was further found during the course of the investigation with both the direct and indirect methods of stimulating the muscle that the work output varied considerably with differences in the type of shock used, such as changes in amperage and voltage, frequency and time relations of the stimuli and the direction of the flow of current.

The methods and apparatus used and the results obtained in the present study will be reported in detail in a later paper.

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BARTLETT, F. C. *Remembering.* Pp. x + 317. Illustrated. Macmillan. $5.00.

BROWN, A. E. *Workbook in Elementary Psychology.* Pp. iii + 182. Macmillan. $1.25.

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