As soon as we have established (10) and (11) we can complete the discussion in the customary manner. An m-chain will be *exact* if its derivative vanishes, it will be *derived* if it is the derivative of some $(m-1)$-chain. By (10), every derived chain will be exact; therefore, the group G_D^m of all derived m-chains will be a subgroup of the group G_E^m of all exact m-chains. The residue group G_E^m mod G_D^m will be the *m-th connectivity group of B*. Finally, by (11), the product of two exact chains will be exact and the product of an exact chain by a derived chain or of a derived chain by an exact chain will be derived. Therefore, the exact chains will generate a sub-ring R_E of R and the derived chains an ideal R_D of R_E. The ring R_E mod R_D will be the *connectivity ring* of the space B.

[1] Cf. a previous note under the same title communicated to these PROCEEDINGS on March 30, 1936. A more detailed account of the theory outlined in the present and previous notes is now being prepared for publication. Moreover, an alternative treatment, from quite another angle, will appear in the *Ann. Math.* for July of this year.

PHYTOPHARMACOLOGICAL REACTIONS OF NORMAL, TOXIC AND ATOXIC SERA

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Introduction.—While physiology is broadly divided by specialists into *zoo*physiology and *phyto*physiology, pharmacology as studied in most of our medical and research institutions has hitherto concerned itself almost exclusively with the effects of drugs on animals (and not plants) so that, strictly speaking, it is *zoo*pharmacology. Fifteen years ago the senior author began a systematic inquiry into the effects of drugs on living plants, as compared with their action on animals, and for convenience designated such studies as *phytopharmacology*.[1] The effects of drugs and poisons on plants may be observed in various ways. Studies may be made on germination of seeds; on the growth of roots, stems, leaves, flowers and fruits; on transpiration, respiration, photosynthesis and other metabolic functions; on protoplasmic streaming and plant movements; and on the action of yeasts, fungi, etc.[2]

A most useful method for qualitative and quantitative investigation was found to be comparison of the root growth of seedlings of *Lupinus albus*. Briefly, the procedure is as follows: Seeds of *Lupinus albus* are soaked in tap water overnight and planted the next morning in finely ground sphag-

num containing sufficient moisture. They are allowed to germinate in the dark until the single, straight and well-demarcated roots are from 30 to 45 mm. long, when they are ready for experimentation. The length of the roots is carefully measured in millimeters and the seedlings are immersed in upright, hard-glass test tubes filled with equal parts of distilled water and Shive solution, containing definite concentrations of magnesium sulphate, diacid potassium phosphate and calcium nitrate.[3] Other series of seedlings from the same crop are placed in physiological solution plus small quantities of unknown chemicals to be tested. The whole outfit is then incubated in the dark at a temperature of 12°C. for 24 hours, after which interval the length of the roots is measured again. The ratio of the growth of roots immersed in solution containing the unknown chemical to the growth of the controls is known as the phytotoxic index or index of growth (index = X/N). In this way any desired number of unknown compounds may be tested simultaneously under the same light, temperature and other conditions. Such studies revealed that living plant tissues are generally more sensitive to the action of certain chemicals than test objects derived from the animal kingdom and logically suggested a study of phytotoxic indices given by bloods from normal and pathological conditions.

Toxic Sera.—Phytopharmacological examination of several thousand normal blood sera in 1% solution gave 75% as the average phytotoxic index. On the other hand, blood sera procured from individuals in certain abnormal physiological and pathological conditions proved to be definitely toxic. Thus phytopharmacological studies established the presence in the blood serum, plasma, whole blood, saliva, tears and other secretions of menstruating women of a toxin (menotoxin) which is absent from those body fluids during the intermenstrual period.[4,5] Again, in this way it was discovered that blood sera from pernicious anemia patients contained a toxin not found in specimens from cases of ordinary secondary anemia, leukemia, cancer, tuberculosis and syphilis.[6,7] Very recently, phytopharmacological examination of a number of sera from patients with malignant aplastic anemia indicated the presence of a toxin in such cases, too. These findings proved useful in facilitating differential diagnosis of pernicious anemia and offered a criterion for evaluation of various therapeutic procedures.[8,9] Another characteristic phytotoxic reaction was discovered by Macht and Pels in connection with a study of blood sera from all kinds of dermatoses. The blood sera of the baffling disease pemphigus revealed a toxicity which differentiated it from that of other skin diseases simulating it.[10,11,12,13] Over 2000 specimens of blood thus studied have established the value of the phytopharmacological test in diagnosing pemphigus from various pathological conditions.

Blood sera from leprosy patients were also found to give a very toxic index of growth, a circumstance which strikingly distinguishes this disease

from tuberculosis and syphilis.[14,15,16] Finally, sera from 100 cases of trachoma indicated that the blood of that disease also exerts a very toxic effect on the growth of Lupinus seedlings.[17,18]

Table 1 shows the toxicity of sera from normal individuals and from patients with the various diseases mentioned above. Table 2 gives the phytotoxic indices of specimens from diseases the sera of which yield a reading that does not substantially deviate from that of normal human blood. It is interesting to note that blood sera from eclampsia are not toxic, a finding which seems to agree with the newer view regarding that dangerous complication of pregnancy, as opposed to the older toxemic theory.[19]

TABLE 1

TOXIC SERA

KIND OF BLOOD SERUM	AV. NO OF CASES	PHYTOTOXIC INDEX
Normal human	500	75%
Menstrual	50	51%
Pernicious anemia	50	44%
Aplastic anemia	10	56%
Pemphigus	200	59%
Leprosy	22	47%
Trachoma	100	48%
Hodgkin's disease	10	60%

TABLE 2

NON-TOXIC SERA

KIND OF BLOOD SERUM	PHYTOTOXIC INDEX
Syphilis	81%
Tuberculosis	78%
Scarlet fever	79%
Measles	80%
German measles	80%
Varicella	80%
Eclampsia	75%
Post-puerperal (12 weeks)	80%

Comparison of Normal Blood Sera of Different Animals.—In the present paper the authors wish to announce new phytopharmacological data, derived from studies of the normal blood sera of various animals and in certain hitherto unexamined pathological conditions. Normal blood sera from a large number of different animals revealed that their toxicity for *Lupinus albus* seedlings was practically identical with that of normal human sera. Phytotoxic indices of from 70 to 75% were given by sera from the horse, ox, sheep, dog, cat, hog, rabbit, opossum, woodchuck, guinea pigs, rats and mice; from the hen, duck, goose, turkey and pigeon; from frogs and toads; and from the stingaree, goldfish, catfish, chub and carp. Reptilian blood was a striking exception. Sera from different species of turtle, from the iguana, chuckawalla and gila monster gave very toxic readings. Curiously enough, the alligator's blood was found to be non-toxic. On the other hand, blood sera from various non-poisonous as well as from poisonous reptiles, i.e., from the black snake, garter snake, bull snake, water snake, rattlesnake, copperhead, moccasin and cobra—all markedly inhibited plant growth. It is interesting to note that the blood of the domestic hen yielded a lower phytotoxic index than that obtained with the serum of any other warm-blooded animal studied.

Atoxic Sera.—During the past year the present authors have been engaged in a study of blood sera from a series of virus diseases, which

yielded some interesting data on these etiological agents as a class. Such blood specimens were obtained from cases of experimental vaccinia in the rabbit and rat, fowl pox in the chicken, herpes simplex in the rat, virus fixé (rabies) in the rabbit and guinea pig, virus III in the rabbit, X-virus in the cat, Rous's sarcoma in the chicken, Shope's fibroma in the rabbit, infectious myxomatosis in the rabbit, Rivers' lymphocytic chorio meningitis in the guinea pig, etc.

The blood sera of all these virus diseases, examined by Macht's phytopharmacological method on *Lupinus* seedlings, yielded indices much higher than those given by specimens from normal animals of the same species and may be designated as *atoxic*. The atoxicity of these sera, of course, is of as much interest as the toxicity of the sera from pernicious anemia, pemphi-

TABLE 3

SERA FROM VIRUS DISEASES

KIND OF BLOOD SERUM	ANIMAL INOCULATED	PHYTOTOXIC INDEX OF CONTROL	PHYTOTOXIC INDEX OF VIRUS SERUM
Fowl pox	chicken	71%	80%
Vaccinia	rabbit	73%	80%
Vaccinia	rat	67%	78%
Herpes simplex	rabbit	72%	84%
Virus fixé	rabbit	75%	61%
Virus fixé	guinea pig	81%	65%
Virus III	rabbit	72%	84%
X-virus	cat	70%	65%
Rous's tumor	chicken	66%	92%
Shope's fibroma	rabbit	77%	96%
Infectious myxomatosis	rabbit	75%	85%
Rivers' lymphocytic chorio meningitis	guinea pig	79%	102%
Poliomyelitis	monkey	61%	62%
Tetanus toxin alone, 86%	rabbit	75%	63%
Strychnine nitrate, 93%	rabbit	77%	61%

gus, leprosy and the other diseases already enumerated. The high readings are of interest also when considered together with similar findings made by Macht and Pels in their studies on blood sera from cases of varicella, measles, German measles and scarlet fever. The chief exception apparently was virus fixé. The toxicity of this blood, however, is probably due to the convulsions rather than to the specific virus of rabies because similar findings were obtained in case of tetanus and strychnine poisoning. Virus fixé alone, or when added to normal blood serum *in vitro*, did not produce a toxic effect.[20] Similarly, pure tetanus toxin, mixed with normal blood in the test tube, and strychnine solutions, added to normal sera in test tubes, produced but little increase in the toxicity, while blood obtained from animals during tetanus or strychnine convulsions was found to be very toxic. The powerful clonic and tonic convulsions of the skeletal

muscles evidently set free poisonous decomposition substances producing a toxic effect on plants.

Table 3 shows the phytopharmacological readings obtained with sera from different virus diseases and with tetanus and strychnine poisoning. Curiously enough, a series of blood specimens from monkeys infected with poliomyelitis did not give readings comparable to those of other virus diseases. Sera from animals thus infected yielded phytotoxic indices within the normal range. The findings are of special interest when compared with the data obtained concerning blood sera from ordinary bacterial and protozoan infections. All the latter gave normal readings. It is well to note that both tuberculosis and syphilis also give phytotoxic indices slightly higher than those of normal sera. The toxicity of trachoma blood, already mentioned, leaves the etiology of that disease still *sub judice*. There are those who regard it as a bacterial infection; others who deem it a virus disease; and still others who consider it a systemic disease complicated by local infection of the eyes. The phytopharmacological examination of sera from 100 trachoma cases leaves that disease still in the doubtful class.

Summary.—(1) Solutions of normal human blood in plant-physiological media produce a definite inhibition of root growth of *Lupinus albus* seedlings, which yield an average phytotoxic index of 75%.

(2) Normal blood sera from a large variety of different animals give phytotoxic indices practically identical with that of normal blood. The principal exception was the blood of reptiles. Blood sera from non-venomous, as well as those of venomous snakes, were all toxic for plant protoplasm.

(3) A marked toxicity for *Lupinus* seedlings is exhibited by sera from certain diseases, i.e., from pernicious anemia, pemphigus and leprosy.

(4) Blood specimens from a series of virus diseases yielded atoxic readings, that is, were less toxic for plant growth than normal blood sera.

(5) Blood sera from monkeys infected with poliomyelitis give readings within the normal range, while that obtained from trachoma patients exerts a marked toxicity.

[1] Macht and Livingston, *Jour. Gen. Physiol.*, **4**, 573 (1922).
[2] Macht, *Science*, **71**, 302 (1930).
[3] Shive, *Physiological Researches*, **1**, 327 (1915).
[4] Macht and Lubin, *Jour. Pharmacol. Exper. Therap.*, **22**, 413 (1924).
[5] Macht and Davis, *Jour. Compar. Psychol.*, **18**, 113 (1934).
[6] Macht, *Jour. pharmacol. Exper. Therap.*, **29**, 461 (1926).
[7] Macht, *Jour. Amer. Med. Assoc.*, **89**, 753 (1927).
[8] Macht and Anderson, *Jour. Pharmacol. Exper. Therap.*, **34**, 365 (1928).
[9] Macht, *Festschrift* of Prof. Emil Bürgi, 228 (1932).
[10] Macht and Pels, *Arch. Dermatol. Syphilol.*, **19**, 640 (1929).
[11] Pels and Macht, *Ibid.*, **23**, 601 (1931).

[12] Pels and Macht, *Ibid.*, **29**, 206 (1934).
[13] Andrews, *Diseases of the Skin*, W. B. Saunders Company, Philadelphia, p. 481 (1930).
[14] Macht, *Proc. Soc. Exper. Biol. Med.*, **27**, 150 (1929).
[15] Macht, *Jour. P. I. Med. Assoc.*, **8**, 523 (1928).
[16] Macht, *Acta Dermatologica*, **18**, 126 (1932).
[17] Macht, *Proc. Soc. Exper. Biol. Med.*, **32**, 349 (1934).
[18] Macht, *Folia ophthalmol. orient.*, **1**, 358 (1935).
[19] Macht and Losee, *Bull. Johns Hopkins Hosp.*, **46**, 217 (1930).
[20] Macht, *Amer. Jour. Physiol.*, **96**, 662 (1931).

CHANGING DIRECT CURRENT TO ALTERNATING CURRENT BY MEANS OF THYRATRONS

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The use of direct current rather than alternating for transmission of electric power has many well recognized advantages, but has been considered impracticable for lack of a satisfactory method of changing the high voltage direct current into alternating current at the end of the line, for distribution to customers.

Seven years ago there was reported in this journal a method of controlling an arc discharge by means of a grid.[1] One of the most interesting applications of such grid-controlled arc devices, or *Thyratrons*, is that of "inverting" direct current into alternating. We have devoted much study to this problem, a brief summary of which is here presented.

The Constant-Current Circuit.—A number of inverter circuits have been investigated. They include (1) the simple phase-commutated parallel type inverter,[2] (2) the series type inverter[3] and (3) the harmonic-commutated inverter.[4] All of these have given excellent operation in the laboratory; but when the data obtained in the small scale laboratory tests have been extrapolated to higher power, new phenomena have been encountered, indicating the need for further research. We have been able to carry out such research, without the wastefulness usually attendant upon large-scale experiments, by using a *constant-current* circuit,[5] in which short-circuit failures do no harm. Complete tests were first made at low power (10 amps., 250 volts) on the bench; then at full voltage and small current (10 amps., 15,000 volts) in a carefully protected room in the laboratory; and finally at full power, viz., 200 amps., 15,000 volts, with engineering equipment kindly loaned to us by Dr. Alexanderson.

The constant-current circuit is shown in figure 1. Beginning at the top, constant-voltage 3-phase alternating current from the power mains is