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# ARE VENOMOUS SNAKES AUTO-TOXIC ?

*AN INQUIRY INTO*

*THE EFFECT OF SERPENT-VENOM UPON THE  
SERPENTS THEMSELVES.*

BY

SURGEON L. A. WADDELL, M.B.,  
DEPUTY SANITARY COMMISSIONER, BENGAL.

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# ARE VENOMOUS SNAKES AUTO-TOXIC?

AN INVESTIGATION

THE EFFECT OF BITE-TREATMENT FROM OWN VENOM  
SERA ON THE SNAKE

BY  
ROBERT I. A. WADSWORTH, M.D.

PHYSICIAN, UNIVERSITY OF CALIFORNIA

1932

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# Are Venomous Snakes auto-toxic ?

AN INQUIRY INTO THE EFFECT OF SERPENT-VENOM UPON THE SERPENTS THEMSELVES.

BY

SURGEON L. A. WADDELL, M.B.,

DEPUTY SANITARY COMMISSIONER, BENGAL.

## INTRODUCTORY.

An interesting question which presents itself in studying the phenomena of serpent-poisoning is that which refers to the insusceptibility or otherwise of a serpent to its own venom, or that of its fellows. And this question is not without a practical bearing upon the treatment of snake-bite: for, were such immunity proved to exist, a study of its conditions might possibly afford indications for combating the action of the venom on man.

Practical bearing of inquiry.

That an animal should be subject to poisoning by one of its own normal secretions, must, *prima facie*, seem improbable, as this would prove detrimental to the individual and to the species. And especially so, when, as in the present case, the exposure to poisoning would be habitual: for snakes are frequently receiving accidental injuries to the mouth, with abrasion of the mucous membrane of the buccal cavity, and thus, not unfrequently, must absorb some of their own venom.<sup>1</sup>

Seeming anomaly of subject.

Should, on the contrary, snakes be proof against poisoning by their own venom, then the problem presents itself of how to account for the organism of the serpent being able to resist a chemical poison which is so deadly to most other animals.

As to whether such insusceptibility really exists, authorities differ widely in

Conflict of opinion on question. opinion.

On the one hand are those who assert the existence of this insusceptibility:—

Fontana, in 1765, experimenting on the European Viper (*Viper aspis?*) concluded that "the venom of the viper is neither a poison to the viper itself, nor to those of its own species."<sup>2</sup>

Favouring view of insusceptibility.

<sup>1</sup> This fact was pointed out long ago by FONTANA in regard to the Viper ('*Treatise on the Venom of the Viper, &c.*,' Skinner's transl. London, 1795, Vol. I, p. 274).

<sup>2</sup> *loc. cit.* p. 34. His experiments on this head, over twenty in number, were admirably conceived and carried out.

Russell,<sup>1</sup> Fayrer,<sup>2</sup> Richards,<sup>3</sup> Nicholson,<sup>4</sup> and Hopley<sup>5</sup> give results of experiments or observations which led them to conclude that the cobra (*Naja tripudians*) is insensible to its own venom or to that of its fellow species. And Indian snake-charmers also have come, by experience or tradition, to hold the same belief.

Breton<sup>6</sup> and Fayrer<sup>7</sup> extended to poisonous snakes in general this principle of insusceptibility.

And analogous experiments upon scorpions, by Bourne<sup>8</sup> and others<sup>9</sup> led to the conclusion that the poison of a scorpion is quite powerless to kill the same individual, or another individual of the same, or even of another species.

On the other hand, Professor Weir Mitchell of Philadelphia—whose very elaborate researches entitle him to the first rank as an authority on snake-venom—states<sup>10</sup> that he felt "at liberty to conclude that the animals (*crotali*) . . . really died from the venom (*crotalus*)." And<sup>11</sup> that the venom of the rattlesnake is "poisonous . . . to its owner" "as well as to other animals." Mitchell's experiments in this direction were confined to rattlesnakes, but it is unlikely that the principle involved should differ materially in the case of the rattlesnake from that of the cobra and other venomous snakes. Popular reports also credit venomous snakes occasionally with biting themselves with rapidly fatal results.<sup>12</sup>

As intermediate between these antagonistic views may be cited the apparently contradictory opinions of Fayrer and of Richards. Although Fayrer, in summarizing his con-

Mixed views.

<sup>1</sup> "An Account of Indian Serpents," Lond. 1796, p. 56. He made one cobra bite another, with the result that the bitten cobra "remained well." "This experiment was repeated with the like result." This cobra some days afterwards was bitten in the belly by another cobra, "blood appeared on the wound but no other consequence followed." While an innocent snake, "a tartutta (*Dipsas trigonata* ?), bitten immediately after in the same part, died within two hours."

<sup>2</sup> "The Thanatophidia of India," Lond. 1872, p. 66 *et seq.*

<sup>3</sup> *Idem*, p. 125 *et seq.*

<sup>4</sup> "Indian Snakes," 2nd Ed., Madras, 1874, p. 145.

<sup>5</sup> "Snakes: Curiosities and Wonders of Serpent Life." Lond. 1882, p. 563.

<sup>6</sup> *Trans. Med. and Phys. Soc.* Calcutta, 1826, Vol. I, p. 170. This conclusion, however, was based upon one solitary experiment on a cobra and a *Daboia russellii* biting each other.

<sup>7</sup> *loc. cit.* p. 64, "The poisonous snakes are not affected by their own poison." In support of this statement is given, in addition to the experiments on cobras, one case of a 'krait' (*Bungarus caeruleus*) bitten by another krait with "no effect" (p. 134); and Richards reports (p. 127, *idem*) another case in which the small bitten krait was "found dead" the following morning. But no further experiments seem to have been made upon kraits, and none upon any of the other species of venomous snakes of India. Regarding the effect of venom upon another venomous snake, Fayrer states (p. 73) that the experiment recorded "seems to prove that the venomous snakes have no power of poisoning each other," and (at p. 64) "in many of the various experiments I have performed, the Cobra, *Daboia* and Krait did not appear able to poison themselves or each other."

<sup>8</sup> *Proc. Roy. Soc.*, p. 20 xlii, 1887. He experimented on three species of scorpions found in Madras, with the view of determining whether scorpions can commit suicide.

<sup>9</sup> RAY LANKESTER and others, from experiments made at Cape Town, about six years ago, arrived, I am informed, at somewhat similar conclusions; but I can find no published record of their results.

<sup>10</sup> "Researches on the Physiology and Toxicology of the Venom of the Rattlesnake." (Vol. XII, Smithsonian Contrib.) Washington, 1860, p. 63.

<sup>11</sup> *Idem*, p. 43.

<sup>12</sup> *Nature*, Vol. XXII, p. 40. And FONTANA and MITCHELL refer to the currency of this belief.

clusions states at one place definitely and unreservedly,<sup>1</sup> that "the poisonous snakes are not affected by their own poison," yet, he notes on the following page that, although "in many of the various experiments I have performed, the Cobra, Daboia, and Krait did not appear able to poison themselves or each other, *some of the experiments render this doubtful.*"

And Richards, although noting<sup>2</sup> that "I believe one cobra cannot poison another" and<sup>3</sup> "I am quite satisfied the cobra cannot kill another cobra;" and recently<sup>4</sup> he relates how healthy cobras, which he kept together in captivity, would "very often on the slightest provocation begin to fight in a most savage" fashion, biting each other fiercely, with the result that "neither of the combatants ever seemed any the worse for the fight." Yet, he notes,<sup>5</sup> "I came to the conclusion, after numerous experiments, that one species of snake could kill another" (by the context) venomous snake of the same species.<sup>6</sup>

Such conflict of opinion upon so elementary a point rendered a further investigation of the subject desirable—especially, as the methods adopted by several of the foregoing experimenters, to elucidate the point at issue, were open to objection.

Desirability of further investigation.

### Part I.—Working Scheme adopted.

The inquiry resolves itself into a consideration of the effect of venom  
Scope of inquiry defined. (1) upon the serpent itself and its own species, (2) upon venomous snakes of other species, (3) upon innocent snakes, (4) upon other reptiles and cold-blooded animals, (5) upon warm-blooded animals; and of the topics arising out of the results of the above investigations.

It is claimed for the present series of experiments that they have avoided  
Sources of experimental error. many of the sources of experimental error to which those of former observers were liable:—

The method usually employed to ascertain the toxic effect of snake-venom  
Injury to viscera, &c., during infliction of bite. upon snakes had been to force one snake to bite another, or its own tail. In this way, however, there is always a probability that the spine or viscera of the bitten snake were crushed, or otherwise grossly injured during the act of biting.<sup>7</sup>

Again, in employing biting as a means of introducing venom, there is un-  
Uncertain introduction of venom by biting. certainty as to the amount of venom introduced; and in some cases uncertainty as to whether any venom at all has been injected—owing to the want of anatomical continuity

<sup>1</sup> *loc. cit.*, p. 64.

<sup>2</sup> *idem*, p. 126.

<sup>3</sup> *idem*, p. 127.

<sup>4</sup> *Landmarks of Snake-poison Literature*. 2nd Ed. Calcutta, 1886, p. 12.

<sup>5</sup> *idem*, p. 12.

<sup>6</sup> No details of the experiments are given.

<sup>7</sup> In Fayer's series of cobras-bitten-by-cobras no *post-mortem* examination appears to have been made to ascertain whether any such fatal injury had been inflicted.



between the venom-duct and the canal of the fang and the more or less erectile nature of the fang—especially in vipers.<sup>1</sup> The “difficulty in making the viper (*Daboia*) insert its long slender fangs into the tough skin of the cobra” is noted.<sup>2</sup> The venom may in part be washed out with the blood escaping from the wounded part.<sup>3</sup> The snake may have recently shed its venom and have little more available.<sup>4</sup> Snakes are also credited with being able to control the flow of their venom, expelling a larger quantity when irritated and rendered furious than in ordinary biting.<sup>5</sup>

A generally recognised difficulty in interpreting the results of such experiments is the frequent mortality of captive snakes. In Fayrer's experiments the majority of the snakes operated upon may have been fresh, but the fact is only noted in regard to one of the bitten snakes. Mitchell's experiments appear to have been made upon snakes which had been in confinement for a considerable time.<sup>6</sup>

The necessity for prolonged observation of the envenomed snake is strongly insisted upon by Mitchell<sup>7</sup> and Claude Bernard<sup>8</sup> on the plea that cold-blooded animals are very much less rapidly affected by venom than the warm-blooded, and hence the necessity, in their opinion, for the snake being kept under observation during a period of several consecutive days.<sup>9</sup>

It is also desirable that the venom experimented with be of ascertained activity. This precaution had been very seldom observed.

In the present series of experiments the above-noted sources of error were to a considerable extent avoided or minimized by the employment of freshly-caught uninjured snakes, by introducing without loss a measured quantity of the venom by the more precise mode of hypodermic injection,<sup>10</sup> by prolonged observation, and by resorting to numerous control experiments to test the activity of the venom.

<sup>1</sup> Dr. MITCHELL notes (*loc. cit.*, p. 25), “I have seen the Rattlesnake strike with great apparent ferocity a number of times, when I have been unable to discover any fang wound whatsoever.” Again, “in some cases it is quite possible that the relations of the fang and the duct are so disturbed that the venom never enters the tooth at all.” And “It sometimes happens that the blow is given, the fang enters, and from the quick starting of the animal injured, or from some other interrupting cause, it is withdrawn so soon that the larger portion of the poison is thrown harmless upon the surface near the wound.”

<sup>2</sup> FAYRER, *loc. cit.*, p. 92.

<sup>3</sup> FONTANA, *loc. cit.*, p. 139.

<sup>4</sup> *idem*, p. 140.

<sup>5</sup> *idem*, p. 139.

<sup>6</sup> *loc. cit.*, p. 61.

<sup>7</sup> *loc. cit.*, p. 63.

<sup>8</sup> “*Leçons sur les Effets des Substances Toxiques, etc.*” 1857, p. 291—quoted by Mitchell, who affords a very full bibliography of serpent-venom literature.

<sup>9</sup> In a fourth of Fayrer's experiments the observations were continued for only one day, and in another fourth for two days only.

<sup>10</sup> FAYRER, *loc. cit.*, p. 75 *et seq.*, records seven cases in which cobra-venom was introduced hypodermically into cobras, but in only two was the observation extended till the sixth day, and in none beyond the sixth day, and no control observations were made.

## Part II.—Effect of Venom upon the Serpent itself, or its own Species.

The experiments under this head were confined to the cobra (*Naja tripudians*), as, with the exception of tree-vipers, other species of venomous snakes were not available.

The Experiments.

And the experiments, with one exception, dealt with the strictly auto-toxic aspect of the subject. Concerning the ability of one venomous snake to poison another individual of the same species, the one experiment (No. XX) here afforded seems almost sufficient when taken in connexion with the numerous experiments recorded by Fayrer<sup>1</sup> and others,<sup>2</sup> in which one cobra was forced to bite another cobra. Moreover, snake-venom (*e.g.*, cobra or *crotalus* venom), from whatever individual derived, is found to possess for each species such constant and well defined properties, that it may well be regarded as a specific chemical poison;<sup>3</sup> and as such it is highly probable that the venom shall act upon another snake of the same species in an identical manner to its action upon the owner of the venom.

The number of cobras operated on was nine, in three series of four, four, and one respectively. I had hoped to operate on a larger

General arrangements.

number, but failed to procure more by my unaided private efforts within the limited time at my disposal.

The first series of experiments was conducted at the end of August of the current year, the temperature of the room in which the snakes were kept, ranging from 81° to 86° Fah. The second series was conducted at the beginning of October, the temperature ranging between 65° and 88° Fah. And the third series at the beginning of November, the temperature ranging between 54° and 78° Fah.

The serpents operated on were all healthy, and had been caught within the previous two to seven days.

In the experiments the venom was extracted in the usual Indian way by causing each cobra to bite through a strip of dried palm leaf<sup>4</sup> stretched across a spoon or valve of a mussel-shell. For injecting the venom an ordinary hypodermic syringe was used. And during the process of injection the serpent was secured by a noose around the neck after the manner recommended by Mitchell.

### Details of the Experiments.

#### First Series of Cobras.

EXPERIMENT I.—A binocellated cobra ('Gokhura'), measuring 53 inches in length, was made to disgorge its venom. About 18 minims of clear venom were

<sup>1</sup> The results of these scattered experiments are collected and analyzed at p. 13 (*q. v.*).

<sup>2</sup> RUSSELL and RICHARDS, *loc. cit.*

<sup>3</sup> For evidence on this head *vide* Part VI.

<sup>4</sup> *Borassus flabelliformis*.

obtained. This venom was mixed with an equal bulk of water, and at 9-15 A.M., 25 minims of this solution were injected hypodermically (and very slightly supra-muscularly) about the middle of the back of this cobra—the same which had yielded the venom. Atmospheric temperature 82° Fah.

This snake was observed every hour during the day and seemed unaffected.

*Next day.*—Active and well. Fierce when disturbed.

3rd " Ditto.

4th " Ditto.

5th " Ditto. Taken out of its cage it bit eagerly, yielding about 9 minims of clear venom.

6th " Ditto.

7th " Ditto.

8th " Ditto.

9th " Ditto. Taken out of its cage it bit vigorously, yielding about 4 minims of slightly cloudy venom. It was immediately thereafter killed and dissected.

*Post-mortem Examination.*—Wound healed, and at site of injection no staining or softening of tissues. All organs strictly normal in appearance.

To test the activity of the venom employed in Experiment I the following two experiments were made immediately after injecting the cobra:—

EXPERIMENT II.—The remainder of the same venom solution as was used in Experiment I was diluted with an equal volume of water, and of this solution 6 minims were injected hypodermically into inner side of thigh of a chicken weighing 14½ ounces. Atmospheric temperature 82° Fah.

9-19 A.M.—Time of injection.

9-22 " —Unable to stand, beak resting on ground.

9-23 " —Convulsions; passing fæces.

9-30 " —Almost dead.

9-33 " —Dead.

EXPERIMENT III.—Nine minims of same solution as used in last Experiment (II) were injected hypodermically into thigh of chicken weighing 15 ozs. Atmospheric temperature 82° Fah.

9-24 A.M.—Time of injection.

9-28 " —Drooping.

9-30 " —Convulsions.

9-35 " —Almost dead.

9-41 " —Dead.

EXPERIMENT IV.—A very fierce monocellated cobra (*Shánkha mutiyá Ki-otíá*) measuring 53½ inches in length, was made to disgorge its venom—yielding about 20 minims. This venom was diluted with an equal bulk of water, and at 10-5 A.M., 25 minims were injected hypodermically about middle of back of this same cobra which had yielded the venom.

This snake was observed every hour during the day and seemed to be unaffected.

*Next day.*—Active and well. Very fierce when disturbed.

*3rd to 9th day.*—Active and well. Very fierce when disturbed. It was taken out of its cage on the fifth and ninth days and bit eagerly, yielding clear venom. On the ninth day it was killed and dissected.

*Post-mortem Examination.*—The skin over site of injection slightly dry and wrinkled, but no subjacent exudation or softening of tissues—only a faint capillary staining subcutaneously at seat of injection. Organs strictly normal in appearance.

To test the activity of the venom used in Experiment IV the following two experiments were made:—

EXPERIMENT V.—Of the remainder of the solution used in Experiment IV, 8 minims were injected subcutaneously into thigh of a chicken weighing 14 ozs.

10-18 A.M.—Time of injection.

10-20 „ —Prostrate; beak resting on ground.

10-25 „ —Convulsions.

10-28 „ —Dead.

EXPERIMENT VI.—Of same solution as used in last experiment 4 minims were injected into thigh of a chicken weighing 10 ozs.—

10-21 A.M.—Time of injection.

10-28 „ —Convulsions.

10-32 „ —Dead.

EXPERIMENT VII.—A monocellated cobra ('*Adyat ki-otiá*'), measuring 43 inches in length, yielded about 12 minims of venom. This was diluted with an equal volume of water, and at 10-45 A.M., 12 minims were injected hypodermically into this same cobra, as in Experiments I and IV.

During the day no effect was observable, and the snake remained well and active up till the ninth day, when it was killed and dissected.

*Post-mortem Examination.*—Wound healed, no softening of tissues or exudation, very slight capillary staining limited to track of syringe-needle. Organs strictly normal.

To test the activity of the venom used in Experiment VII the following two experiments were made:—

EXPERIMENT VIII.—Of the remainder of the solution used in last experiment No. VII, 8 minims were injected subcutaneously into thigh of a chicken weighing 14 ozs.—

10-51 A.M.—Time of injection.

11-10 „ —Convulsions.

11-23 „ —Dead.

EXPERIMENT IX.—Of the same solution as was used in last experiment 4 minims were similarly injected into a chicken weighing 13 ozs.—

10-53 A.M.—Time of injection.

11-11 „ —Convulsions.

11-30 „ —Dead.

EXPERIMENT X.—A small binocellated cobra ('*Kála Gokhura*'), measuring 34 inches in length, yielded about 10 minims of venom. This was mixed with double its bulk of water, and 15 minims of this solution injected into this same cobra. The injection appeared to be without effect. The snake was observed several times during that day and following days, and found at all times to be actively on the alert.

On the fifth and ninth days following injection, it bit eagerly, yielding clear venom.

On the ninth day it was killed and dissected.

*Post-mortem Examination.*—Wound healed, no exudation, softening, of staining of the tissues at seat of injection. Organs strictly normal.

To test the activity of the venom used in Experiment X, the following two experiments were made immediately thereafter:—

EXPERIMENT XI.—Of the remainder of the solution used in Experiment X, 8 minims were hypodermically injected into a chicken weighing 14 ozs.—

11-28 A.M.—Time of injection into thigh of chicken.

11-37 „ —Convulsions.

11-42 „ —Dead.

EXPERIMENT XII.—Of the same solution as was used in last experiment 4 minims were similarly injected into a chicken weighing 10 ozs.—

11-30 A.M.—Injection into chicken's thigh.

11-36 „ —Convulsions.

11-43 „ —Dead.

#### Second Series of Cobras.

EXPERIMENT XIII.—A very large binocellated cobra, measuring 59½ inches in length, yielded about 9 minims of straw-coloured clear venom. This was mixed with an equal quantity of water, and of this solution 15 minims were injected hypodermically about middle of back.

During that day the snake appeared unaffected, and no change was noted during the subsequent fourteen days. On the fifteenth day after injection, the snake was active and furious, it bit vigorously, yielding a small amount of clear venom—the greater portion escaping into snake's mouth. It was immediately thereafter killed and dissected. Temperature during its captivity ranged between 65° and 78° Fah.

*Post-mortem Examination.*—No morbid appearances externally over site of injection. Subcutaneously slight limited swelling about size of small split-pea

beneath fascia, which had been pricked by injection needle, but no softening or exudation. Viscera strictly normal in appearance.

To test the activity of the venom used in Experiment XIII, the following experiment was made:—

EXPERIMENT XIV.—The remaining 3 minims of the solution used in experiment XIII were injected hypodermically into inner aspect of right thigh of a chicken weighing 15 ozs.—

- 11- 9 A.M.—Time of injection.
- 11-17 „ —Head drooping.
- 11-20 „ —Lying on side paralysed.
- 11-22 „ —Convulsions.
- 11-33 „ —Nearly dead.
- 11-35 „ —Dead.

EXPERIMENT XV.—A large binocellated cobra ('*Kálá Gokhura*'), measuring  $47\frac{3}{4}$  inches in length, yielded about 12 minims of light straw-colored clear venom. This was mixed with an equal bulk of water, and of this solution 20 minims were injected hypodermically about middle of back of this same snake. Temperature as in Experiment XIII.

During that day no change was apparent. Nor was any change evident up to the fifteenth day after injection, when the snake was taken out of its cage, and it bit fiercely, yielding clear venom. It was immediately thereafter killed and dissected.

*Post-mortem Examination.*—Slight wrinkling and dulness of skin over site of injection. No exudation or staining or softening subcutaneously; but point of needle had pricked the sheath of the spinal muscles, and sub-fascially around site of puncture was a small inflammatory nodule about size of a small pea, red on section, and of cheesy consistence. Viscera strictly normal in appearance.

To test the activity of the venom used in Experiment XV, the following experiment was made:—

EXPERIMENT XVI.—The remaining 4 minims of the solution used in Experiment XV were injected hypodermically into thigh of a fowl weighing 24 ozs.—

- 11-39 A.M.—Time of injection.
- 11-46 A.M.—Beak resting on ground.
- 11-53 A.M.—Lying on side with convulsive gaspings.
- 11-59 A.M.—Dead.

EXPERIMENT XVII.—A vigorous monocellated cobra ('*Shankha mutiya Ki-otíá*'), measuring  $46\frac{3}{4}$  inches in length, yielded about 15 minims of clear colorless venom. This was mixed with an equal bulk of water, and 25 minims of this solution were injected hypodermically about middle of back of this cobra.

Temperature as in Experiment XIII. During that day it seemed unaffected. Nor did it seem affected during the fourteen subsequent days. On the fifteenth day after injection it was taken out of its cage and it bit fiercely, yielding clear venom. It was immediately thereafter killed and dissected.

*Post-mortem Examination.*—No local signs whatsoever. Organs strictly normal in appearance.

To test the activity of the venom used in Experiment XVII, the following experiment was made:—

EXPERIMENT XVIII.—The remaining 5 minims of the same solution used in Experiment XVII were injected hypodermically into the thigh of a fowl weighing 30 ozs.—

12 noon.—Time of injection.

12-4 P.M.—Sitting with beak resting on ground.

12-20 „ —Convulsions.

12-23 „ —Dead.

EXPERIMENT XIX.—A large binocellated cobra, measuring  $51\frac{3}{4}$  inches in length, had 7 grains of cobra venom (obtained from another cobra one month previously and of ascertained activity<sup>1</sup>) dissolved in 15 minims of water injected hypodermically about middle of back. Temperature as in Experiment XIII.

During that day it seemed to remain unaffected, and so it also remained during the following fourteen days. On the fifteenth day following the injection, the snake was taken out of its cage, and bit vigorously, yielding clear venom. It was immediately thereafter killed and dissected.

*Post-mortem Examination.*—No local signs evident. Viscera generally were slightly congested, but not otherwise abnormal in appearance, and no fluid extravasation had occurred into any of the cavities.

#### Third Series of Cobras.

EXPERIMENT XX.—A large active binocellated cobra, measuring 58 inches in length, yielded about 16 minims of clear venom. This was diluted with an equal bulk of water, and of this solution 28 minims were injected hypodermically about middle of back of this same cobra. Temperature  $70^{\circ}$  Fah.

During the day it seemed to remain unaffected, nor did it appear affected during the subsequent fifteen days.

On the fifteenth day it was killed and dissected.

*Post-mortem Examination.*—Skin slightly dry and wrinkled over seat of injection, very faint localized staining subcutaneously at point where needle penetrated cuticle. The subjacent muscle here to extent of about size of split-pea semi-diffluent, but free from purulent products. Viscera strictly normal in appearance.

<sup>1</sup> One and a half grains dissolved in water killed in 20 minutes a chicken weighing 16 ozs.

To test the activity of the venom used in Experiment XX the following experiment was made immediately after injecting the cobra:—

EXPERIMENT XXI.—Two minims of the same solution as was used in Experiment XX were hypodermically injected into thigh of a fowl weighing 3½ ozs.—

8-25 A.M.—Time of injection.  
 8-50 „ —Drooping in sitting position.  
 9-5 „ —Beak resting on ground.  
 9-15 „ —Lying on side.  
 9-50 „ —Dead.

The results of these experiments unequivocally demonstrate that the cobra is practically, if not wholly, insusceptible to the toxic action of its own venom. In the first series, the cobras were kept under observation for nine days, in the second series for fifteen days, and in the third for fifteen days. And the fact that each series of experiments was conducted under different conditions as to locality,<sup>1</sup> elevation above sea-level, temperature, and season, tended to eliminate local sources of experimental error.

In view of the absolute uniformity of results which has obtained throughout these experiments, it becomes desirable to review the details of those experiments by Mitchell and Fayrer which seem to have been attended by exceptional or anomalous results, in order to ascertain whether the seemingly anomalous results may not be attributable to accident.

The experiments recorded by Fayrer upon cobra-venom *versus* the cobra are 23 in number, *vis.* 16 on cobras bitten by cobras and 7 in which cobra-venom was injected hypodermically into cobras. In these 23 experiments there were only three deaths. Reviewing the particulars of these three fatal cases it is to be remarked in regard to the *first* case,<sup>2</sup> that no *post-mortem* examination was made to ascertain whether the needle had not entered a blood-vessel or viscus, or the non-existence of any other obvious cause of death. Neither is it stated whether the snake was a fresh or vigorous one. In six further experiments of a similar nature the cobras are reported to have survived.

In regard to the *second* fatal case<sup>3</sup>—a young cobra “10 inches long” and “only 10 or 14 days old”—the marvel is that it survived so long (six days) in captivity after having been wounded by biting.

In the *third* case<sup>4</sup> the cobra was reported next day “perfectly well,” and it seems to have lived for six days. The death may have been due to starvation,

<sup>1</sup> Two of the places were about 200 miles apart.

<sup>2</sup> *loc. cit.*, p. 75.

<sup>3</sup> *loc. cit.*, p. 99.

<sup>4</sup> *idem*, p. 120.



septicæmia, or other accidental causes. No *post-mortem* examination appears to have been made.

Thus, in regard to neither of these three cases is there evidence to show that the fatal event was due to the venom. On the contrary, the likelihood that death resulted from other and accidental causes is so great that these three experiments may well be eliminated from the series; and when so eliminated, there remain 20 experiments, with no deaths.

Mitchell records<sup>1</sup> seven experiments on rattlesnakes with rattlesnake venom, and concludes that "the above experiments were on the whole so definite in their results that I did not think it necessary to multiply them," and that these rattlesnakes "really died from the venom."

An examination, however, of the details of his experiments renders it difficult to conceive how Dr. Mitchell was led to such a conclusion.

But before examining the particulars of these experiments *seriatim*, it is necessary to remember, *firstly*, that these snakes had been for some time in captivity—the record of these experiments being prefaced by the remark "at the close of a series of experiments on warm-blooded (animals) I made use of some of my largest snakes in the following manner."<sup>1</sup> And, *secondly*, that these snakes appear to have been repeatedly subjected to extremely rough handling and forcible compression of the poison-glands during extraction of the venom—a process so severe that it is noted,<sup>2</sup> "One snake in every four died within two to five days" from the mere effects of the process for extracting their venom. And to this process the snakes of Experiments I, III, V, VI and VII, seem to have been subjected during their final experiment.

In Experiment I, the snake did not die till the fourteenth day after being bitten, and it presented no signs of viper-poisoning.<sup>3</sup> In Experiment II, the snake "died on the fourteenth day. The wound was apparently healthy." . . . "The blood was uncoagulated, but there was no other visible lesion of any internal organ." Concerning Experiment III, it is noted, "In all probability this serpent died from some other cause than venom-poisoning." In Experiment IV the snake "recovered," although it bit itself three times on a part from which skin had been removed, throwing out "a good deal of venom which was thrust deeply into the muscles of wounded part." "No blood was effused" and "at the close of two weeks this snake was healthy and bit eagerly." In Experiment V, although the snake lived for 36 hours after injection of poison, there appears to have been no extravasation of blood, except that the stomach "contained bloody mucus." The wound "was not stained with blood." "The heart was full of *clotted* blood." In Experiment VI, where the snake lived for about three days, it is recorded that the local appearances were even "less extensive" than in last

<sup>1</sup> *loc. cit.*, p. 61 *et seq.*

<sup>2</sup> *idem*, p. 29, the author remarking that "it is not impossible that too severe a compression of the venom gland may produce rupture of its substance and consequent blood-poisoning."

<sup>3</sup> Fluidity of blood with bloody extravasations are the leading physical signs of viper-poisoning.

experiment. "The interior organs were healthy, and the heart contained loose soft clots." In Experiment VII, the snake died on the seventh day and had bloody extravasations into the peritoneal cavity, and the intestines were spotted with ecchymoses. But such appearances are common to death from septicæmia, and it is noted that the wound "penetrated the muscles, which were dark and much softened."

Thus, taking this series of Dr. Mitchell's observations as a whole, and Mitchell's inference from his experiment scarcely warranted. keeping in view the above-noted sources of error to which these experiments were especially subject, we find that the results, far from "definitely" warranting the conclusion that the rattlesnakes "really died from the venom," can more readily be interpreted as supporting quite an opposite conclusion. And this opposite conclusion gains from Dr. Mitchell further support from his observation<sup>1</sup> that in the "numerous instances in which I had wounded the mouths of rattlesnakes or torn the *vagina dentis* while robbing them of poison, on none of these occasions have any serious results followed the injury, even where the venom had fallen upon the abraded surfaces in considerable amount."

Summarizing the results of all the foregoing observations, it will be seen General conclusion on the auto-toxicity of venom. that, when the suspicious elements are eliminated from the experiments of Mitchell<sup>2</sup> and of Fayrer, the results are in accordance with those of the present series of experiments, and also with the recorded rough experiments of Russell and of Richards upon cobras biting each other; and, that they generally confirm and extend the principle formulated by Fontana in regard to viper-venom, *viz.* "that the venom . . . is neither a poison to the snake itself nor to those of its own species."<sup>3</sup>

In inquiring into the cause of venomous snakes (all?) being immune to their own venom or that of their species, it becomes necessary to ascertain the effect of venom upon snakes of other species—venomous and non-venomous, as well as upon other cold-blooded animals. As to *warm-blooded* animals, all modern observers seem agreed in confirming the conclusion arrived at by Fontana from experiment on all the available warm-blooded animals in Italy, *viz.*, that venom "is a poison to *all* warm-blooded animals."<sup>4</sup>

### Part III.—Effect of Venom on Venomous Snakes of other Species.

For experiment under this head, only pit-vipers, three in number, were available; my endeavours to procure other kinds of venomous snakes so late in the season having proved unsuccessful.

<sup>1</sup> *loc. cit.*, p. 63.

<sup>2</sup> Further experiments on rattlesnakes are desirable in order to remove all ambiguity.

<sup>3</sup> *loc. cit.*, p. 34.

<sup>4</sup> *loc. cit.* p. 273. Certain American writers consider the pig immune to venom (*New York Med. Jour.*, p. 54, 1884), but more authentic evidence on this point is needed.

Upon these three vipers the effect of cobra-venom was tried. The details of the experiments are as follow :—

Effect of cobra-venom on *Trimeresurus erythrurus*.

EXPERIMENT NO. XXII.—A newly caught vigorous large *Trimeresurus erythrurus*, measuring  $29\frac{1}{2}$  inches in length, had, at 8-15 A.M., 4 grains of fresh dry cobra-venom of ascertained activity dissolved in 12 minims of water, and injected hypodermically about middle of back. Atmospheric temperature  $82^{\circ}$  Fah.—

- 8-15 A.M.—Time of injection.
- 8-18 „ —Actively crawling up sides of cage.
- 8-30 „ —Still active.
- 9 „ —Very quiet.
- 9-15 „ —Dead.

*Post-mortem dissection*.—Heart continued pulsating till 1-5 P.M. The injection had been strictly hypodermic. Muscles not wounded, and only a faint streak of capillary hæmorrhage at seat of injection. Viscera normal in appearance.

EXPERIMENT NO. XXIII.—A newly caught very active small *Trimeresurus erythrurus*, measuring  $12\frac{3}{4}$  inches, had injected hypodermically about middle of back 8 minims of same solution of cobra-venom, of which 5 minims had killed a chicken weighing 1lb in 20 minutes. Atmospheric temperature  $85^{\circ}$  Fah.—

- 11-17 A.M.—Injection.
- 11-19 „ —Actively moving.
- 11-25 „ —Scarcely able to move.
- 11-29 „ —When turned over on back, unable to regain position.
- 11-36 „ —Exhibits no movement unless pinched, and then only faintly moves the tail and neck.
- 11-42 „ —Dead.

*Post-mortem dissection* showed the injection to have been purely hypodermic. The snake had been captured only a few minutes before, and was uninjured during capture, and during injection was not roughly handled.

EXPERIMENT NO. XXIV.—A freshly caught active *Trimeresurus gramineus*, measuring 27 inches long, had, at 8-45 A.M., 7 minims of fresh cobra-venom, diluted with an equal bulk of water, injected hypodermically about middle of back. Atmospheric temperature  $82^{\circ}$  Fah.—

- 8-45 A.M.—Injection.
- 8-50 „ —Actively moving.
- 9-15 „ —Scarcely able to move.
- 9-25 „ —Almost dead.
- 9-32 „ —Dead.

*Post-mortem dissection* showed that the injection had been very slightly intra-muscular as well as subcutaneous. Only faint streak capillary hæmorrhage locally. Viscera normal in appearance.

I here present a summary of all the published observations I can find, relating to the toxic action of venomous snakes upon each other. The snakes comprise the Cobra, *Daboia*, *Bungarus fasciatus* et *cæruleus*, and *Echis carinata*. And the toxic effect was estimated by forcing one snake to bite another of a different species—

NATURE OF OBSERVATION.	Serial No. of Case.	Observer.	Page of 'Thanatophidin of India' where reported.	Time under observation after bite.	Result.	REMARKS.
Cobra biting <i>Daboia russellii</i> .	1	Breton <sup>1</sup>	...	2 days	"No effect."	
	2	Fayrer	73	5 "	" "	
	3	"	80	6 "	" "	
	4	"	85	Not stated	"Remained well."	
	5	"	85	" "	" "	
	6	"	92	" "	" "	
	7	"	98	2½ days	"No change."	
	8	"	101	7 "	" "	
Cobra biting <i>Bungarus fasciatus</i> .	1	Fayrer	74	29 hours	Died	Had been twice bitten by a large cobra.
	2	"	85	4 days	"	"Lung and thorax filled with blood," indicating visceral or vascular lesion.
	3	"	92	18½ hours	"	Been bitten three times.
	4	"	100	5 days	"Well and active."	Died thirteen days after bite.
	5	"	107	1 day	Died	"Appears to have received some injury about head and neck."
	6	"	108	2½ hours	"	Bitten twice 'near tail.'
	7	"	119	5 days	"	Day following bite "perfectly well." When died "wound had become putrid."
Cobra biting <i>Echis carinata</i> .	1	Fayrer	140	20 hours	Died.	
	2	"	"	1 day	"	
Cobra biting <i>Bungarus cæruleus</i> .	1	Fayrer	124	10 minutes	Died	"The fangs of the cobra were heard to strike the krait's spine."
	2	Richards	125	1 day	"Found dead."	It is noted, "Death cannot be attributed to rough handling."
	3	"	127	1 hour	Died	The krait ( <i>Bungarus</i> ) was only 1 foot 10 inches long, and the cobra was full grown.
	4	"	127	1½ days	"Quite well"	Krait was 2½ feet long.
	5	"	142	0 "	"No result"	
<i>Daboia russellii</i> biting Cobra.	1	Russell <sup>2</sup>	...	Not stated	"No symptoms."	
	2	Breton <sup>1</sup>	...	" "	Not affected.	
	3	Fayrer	80	6 days	"No effect."	
	4	"	83	1 day	"No change."	
	5	"	"	44 hours	Died	The cobra was 'full grown.' No <i>post-mortem</i> examination seems to have been made.

<sup>1</sup> loc. cit., p. 175.

<sup>2</sup> loc. cit., p. 85.

NATURE OF OBSERVATION.	Serial No. of Case.	Observer.	Page of 'Thanatophidin of India' where reported.	Time under observation after bite.	Result.	REMARKS.
<i>Daboia russellii</i> biting Cobra—contd.	6	Fayrer	83	1½ days .	Little, if any effect.	Cobra was only "10 or 14 days old." Death "possibly from injury done by the viper's enormous fangs." But no <i>post-mortem</i> examination seems to have been made.
	7	"	"	1½ " .	"No effect."	
	8	"	85	2 " .	Little, if any effect.	
	9	"	92	5 " .	"Quite well."	
	10	"	99	4 " .	Died .	
	11	"	101	7 " .	"No change."	
	12	Richards	127	1 day .	Died .	
<i>Daboia</i> biting <i>Bungarus fasciatus</i> .	1	Fayrer	100	13 days .	"Remained unaffected."	
<i>Daboia</i> biting <i>Bungarus caruleus</i> .	1	Fayrer	140	Not stated .	"Unaffected"	
<i>Bungarus fasciatus</i> biting Cobra.	1	Fayrer	69	1 day .	"Well."	
<i>Bungarus caruleus</i> biting Cobra.	1	Fayrer	120	2 days .	"Found dead."	Morning following bite was "unaffected."
	2	"	133	7 " .	"Not, nor has been, affected."	
	3	"	134	32 minutes .	Died .	Cobra was only 14 inches long, and <i>krait</i> was 48 inches.
	4	"	140	4 days .	"Quite well."	Cobra was of "small size." It is noted, "The death may not be due to the bite, as many of the snakes are dying at present."
	5	Richards	125	3 " .	"Well."	
	6	"	127	1 day .	Died .	
	7	"	142	2 days .	"	
<i>Bungarus caruleus</i> biting <i>Echis</i> .	1	Fayrer	138	Not stated .	"Not affected."	
<i>Echis carinata</i> biting Cobra.	1	Fayrer	136	1½ days .	Died .	During day of bite "no effect apparent."
<i>Echis</i> biting <i>Bungarus caruleus</i> .	1	Fayrer	136	2 days .	"Quite well."	
	2	"	138	Not stated .	"Not affected."	
	3	"	140	4 days .	"No effect."	

In analyzing the experiments shown in the table, it is to be remembered that they were subject to most of the experimental errors already referred to in Part I, so that many of the experiments must be eliminated. When the series is thus modified many of the divergent results disappear; but much uncertainty must remain until more exact experiments are forthcoming. At present the nett result of these experiments may be stated as showing that—

Analytic summary of results.

- (1) the Cobra-bite is inoperative on *Daboia russellii*, doubtfully operative on *Bungarus fasciatus* and *Bungarus cæruleus*, and fatal to *Echis carinata*;
- (2) the *Daboia*-bite is inoperative on the Cobra and *Bungarus fasciatus* and *Bungarus cæruleus*; but the experiments with *Bungarus* being solitary ones and merely by biting are inconclusive;
- (3) the *Bungarus cæruleus*-bite is inoperative on the Cobra and doubtfully so on *Echis*;
- (4) the *Bungarus fasciatus*-bite is apparently inoperative on the Cobra;
- (5) the *Echis*-bite is inoperative on *Bungarus cæruleus*.

My experiments showed that Cobra-venom is rapidly fatal to two species of the green tree-viper (*Trimeresurus*).

#### Part IV.—Effect of Venom on Innocent Snakes.

The results of my experiments upon the effect of venom on innocent snakes—16 in number—are shown in the following table. It is to be noted that all the snakes operated on had been newly caught, and, except where otherwise stated, vigorous and uninjured; the solution of venom was freshly made and subcutaneously injected about middle of back, and the activity of the venom solution had in every case been ascertained by control experiments on fowls. The snakes nearly always passed fæces during, or immediately after, the operation; but this was also done occasionally by the cobras while being gently manipulated and may be due to mere excitement. That the injection had been purely subcutaneous was ascertained by *post-mortem* dissection in every case, except where otherwise stated. The atmospheric temperature ranged between 80° and 86° Fah.

Own experiments with cobra-venom.

## Experiments with Cobra-venom on Innocent Snakes.

Experiment No.	SPECIES OF SNAKE.	Length of Snake in inches.	Amount of Venom injected (approximately).	Result.	Duration of life from time of injection.	Post-mortem examination.	REMARKS.
XXV	<i>Ablabes rapii</i>	18½	½ grain	Died	95 mins.	Very slight streak capillary hæmorrhage at seat of injection.	
XXVI	<i>Simotes bicatenatus</i>	26	¼ gr. and after 4 days 1½ grs.	Doubtful.	Doubtful.	.....	A very strong thick- et snake. Was still alive, although very sluggish se- cond day after last injection, or sixth day after first in- jection.
XXVII	<i>Tropidonotus subminiatus.</i>	22½	½ gr.	Died	11 hours	No obvious exudation or discoloration at site of injection.	
XXVIII	<i>Simotes bicatenatus</i>	8½	½ gr.	"	2¾ "	None made.	
XXIX	<i>Dipsas gokool</i>	28½	1¼ grs.	"	3¼ "	"	
XXX	<i>Dipsas gokool</i>	30¼	1¼ "	"	4 "	"	
XXXI	<i>Simotes bicatenatus</i>	24½	2 "	"	1¼ days.	Very slight inflammatory exudation, but no softening at site of injection. Viscera generally congested, intestines injected. No bloody fluid in cavities.	
XXXII	<i>Dipsas hexagonata</i>	32½	¾ gr.	"	5 hours	None made.	
XXXIII	<i>Dendrophis pictus</i>	33½	¾ "	"	55 minutes	"	
XXXIV	<i>Tropidonotus subminiatus.</i>	30½	1½ grs.	"	55 "	"	
XXXV	<i>Tropidonotus quincunciatus.</i>	17½	½ gr.	"	10 hours.	At site of injection slight swelling from exudation, but no hæmorrhage.	
XXXVI	<i>Uropeltis, sp.</i>	15	½ "	"	65 mins.	None made	A young specimen.

Experiment No.	SPECIES OF SNAKE.	Length of Snake in inches.	Amount of Venom injected (approximately).	Result.	Duration of life from time of injection.	Post-mortem examination.	REMARKS.
XXXVII.	<i>Gonyosoma gramineum</i>	16½	½ gr.	Died .	85 Mins.	None made .	Had received considerable flesh-wound during capture, but was newly caught and very active.
XXXVIII	<i>Ablabes collaris</i> . . .	23	1 "	" .	29 "	"	
XXXIX .	<i>Gonyosoma gramineum</i>	19	1 "	" .	45 "	Injection proved to be partially intramuscular (very superficially) and attended by slight capillary hæmorrhage.	Had received severe wound below neck during capture.
XL .	<i>Tropidonotus quincunciatus.</i>	37¾	2 grs.	" .	5¼ hours.		

In all these experiments the cobra-venom proved to be more or less rapidly fatal.<sup>1</sup> The duration of life after injection of the venom was in direct ratio (*a*) to the amount of venom administered, and (*b*) to the robustness of the individual operated on: the more delicate tree-snakes rapidly succumbed, while the relatively shorter but more robust *Simotes* offered much greater resistance to the action of the venom. The snakes operated on were generally of small size, as the larger species of non-venomous snakes, *e.g.* the python and rat-snake (*Ptyas*), could not at the time be obtained for experiment.

The results recorded by previous observers are shown in the following table. The snakes were *bitten* by the venomous species; the biting snakes, with two exceptions, being cobras. In addition to those given in the table are three experiments by Fontana<sup>2</sup> in which innocent snakes, called respectively 'aspick,' 'adder,' and 'orvai' were bitten by vipers; but beyond 'slight torpidity' in one case no other effect was noted.

In experiment No. XXVI the fact of actual death was not ascertained; but this snake when last seen was evidently dying; and the deaths of two others of the same species were duly observed—*Vide Experiments Nos. XXVIII and XXXI.*

<sup>2</sup> *loc. cit.*, p. 39.



## Experiments on Innocent Snakes bitten by Venomous Snakes.

No.	BITING SNAKE.	BITTEN SNAKE.	Observer.	Length of Snake.	Result.	Duration of life from time of bite.	REMARKS.
1	Cobra . . .	'Nooni paragodoo' ( <i>Zamenis fasciolatus</i> ?).	Russell <sup>1</sup> .	...	Died	1½ hours.	
2	" . . .	'Tartutta' ( <i>Dipsas trigonata</i> ?).	" .	"	"	2 "	
3	" . . .	'Dhonor' ( <i>Tropidonotus sp.</i> ?).	Breton <sup>2</sup> .	...	"	2½ "	
4	" . . .	<i>Ptyas mucosus</i> . . .	Fayrer <sup>3</sup> .	...	Nil.	...	Only observed for one day.
5	" . . .	" . . .	" .	8 feet .	Died	7 days .	3 days after bite reported "quite well."
6	" . . .	" . . .	" .	6 " .	"	1½ "	Bitten at part where scales scraped off—the cobra had just fatally bitten a lizard.
7	" . . .	" . . .	" .	...	Nil.	...	Only observed for one day.
8	" . . .	" . . .	" .	"	"	"	Only observed for one day.
9	" . . .	" . . .	" .	'Full grown.'	"	...	Only observed two days.
10	" . . .	" . . .	" .	'Large'	"	...	Had ten 'drops' cobra-venom (11 days old) injected hypodermically under mm. of mouth. 'Several days later' it was 'quite well.'
11	" . . .	" . . .	" .	'Small'	Died	13 minutes.	
12	" . . .	<i>Dendrophis pictus</i> . . .	" .	40 inches	"	9 "	} Was not spine crushed in biting?
13	" . . .	" . . .	" .	'Smaller than above.'	"	7 "	
14	" . . .	<i>Ptyas mucosus</i> . . .	" .	...	"	6¾ hours .	Was bitten three times by two cobras.
15	" . . .	<i>Dendrophis (sp.)</i> . . .	" .	'Small'	"	41 minutes	Bitten by two cobras.
16	" . . .	<i>Dryophis (sp.)</i> . . .	" .	3½ feet .	"	36 "	" "
17	" . . .	<i>Ptyas mucosus</i> . . .	" .	'Large'	"	27½ hours.	
18	" . . .	" . . .	" .	'Small'	"	21 minutes	Twice bitten.
19	" . . .	<i>Passerita mycterizans</i> . . .	" .	3 feet .	"	2 "	"Body swollen where bitten." ( <i>Qu.</i> from hæmorrhage?) No <i>post mortem</i> exam. made.
20	" . . .	" . . .	" .	'Small'	"	17 "	
1	Daboia . . .	<i>Ptyas mucosus</i> . . .	" .	'Large'	Died	*	* After bite 'sluggish.' "Recovered subsequently." On seventh day again bitten and died in 1½ days.
1	<i>Bungarus caruleus</i> .	<i>Ptyas mucosus</i> . . .	" .	2 fe .	Died	5½ hours .	

<sup>1</sup> *loc. cit.*, p. 56.<sup>2</sup> *Idem*, p. 170.<sup>3</sup> *Idem*, p. 66 et seq.

In these experiments the smaller snakes all died more or less rapidly from the cobra bite, in accordance with the results of my own experiments with cobra-venom as previously given. In the case of the large and powerful 'rat-snake' (*Ptyas mucosus*), however, the results were very varied. This want of uniformity is doubtless in part owing to the experimental errors incidental to biting as a means of introducing the poison, and to insufficiently long observation. But, after allowing for these sources of error, the series of experiments seems sufficient to indicate that the full-grown rat-snake offers a considerable resistance to the action of the venom.

General summary of results.

Experiments on pythons, and further and more exact experiments on rat-snakes, are desirable.

### Part V.—Effect of Venom on other Cold-blooded Animals—vertebrate and invertebrate.

A considerable number of observations are available under this head.

Mitchell refers<sup>1</sup> to an experiment with rattlesnake venom upon an alligator as "well illustrating . . . the activity with which venom may be absorbed by mucous

On Alligator.

membranes."

Fontana<sup>2</sup> found that the smaller lizards "scarcely survive its (the viper's) bite for a few minutes." Fayer<sup>3</sup> records two cases of the large water-lizard (*Varanus flavescens*) bitten

On Lizards.

by cobras with a fatal result in 27 and 46 hours respectively. Wall reports<sup>4</sup> a lizard (*Calotes versicolor*) dying in 10 minutes from 4cc. of *daboia* venom.

Fontana<sup>5</sup> recorded 11 experiments on turtles with the relatively mild viper-venom: three of the turtles died and eight were practically unaffected. Cantor<sup>6</sup> relates two cases

On Tortoise and Turtle.

of Tortoise (*Trionyx gangeticus*) bitten in the lip by sea snakes: the one bitten by a *Hydrophis schistosa*, 2 feet 9 inches in length, died in 28 minutes; and the other bitten by a *H. striata*, 3 feet long, died in 46 minutes.

Fontana records<sup>7</sup> results of experiments on 86 frogs bitten by vipers, and found that "some died in less than half an hour, others in an hour, and others again in two or three

On Frogs.

hours;" And that generally frogs "die in a few hours if bitten by a viper." Mitchell records<sup>8</sup> experiments on ten frogs with *crotalus*-venom and all died:

<sup>1</sup> *loc. cit.*, p. 46.

<sup>2</sup> *loc. cit.*, p. 41.

<sup>3</sup> *loc. cit.*, pp. 68 and 70.

<sup>4</sup> 'Indian Snake poisons.' London, 1883, p. 62.

<sup>5</sup> *loc. cit.*, p. 39.

<sup>6</sup> *Trans. Zool. Soc.* (Lond.) Vol. II, 1841, p. 310.

<sup>7</sup> *loc. cit.*, p. 97 et seq.

<sup>8</sup> *loc. cit.*, p. 55.

two dying in an hour, and two living for three to five days. Fayerer gives an account<sup>1</sup> of three large frogs (*Rana tigrina*) bitten by cobras: two of these died in 26 minutes and in 60 minutes respectively, while the third, which had been bitten by a cobra which had just bitten other animals four times, was reported next day to have "remained quite well."

Brunton and Fayerer<sup>2</sup> give three experiments on frogs with small doses of cobra-poison—the frogs dying within 12 hours. Several other frogs were poisoned by them with cobra-venom to observe the effects on nervous and muscular irritability. Wall reports<sup>3</sup> four frogs injected with cobra-venom dying in 40, 67, 79 minutes, and 4 hours respectively; and one frog as recovering from .77 grs. *daboia*-venom, while a similar amount of cobra-venom proved fatal in about an hour.

Of my experiments on frogs, the leading results are here tabulated. The venom was in watery solution and injected into the dorsal lymphatic sac. Atmospheric temperature ranged from 80° to 86° Fah. Control experiments were made on two frogs similar in size to the first two of the series by injecting a similar quantity of water into sac; but the frogs remained unaffected, and on the second day they were still well.

*Experiments with Cobra-venom on Frogs.*

Experiment No.	SPECIES OF FROG.	Size.	Amount of Venom injected (approximately).	Result.	Duration of life from time of injection.	Post-mortem examination.	REMARKS.
XLI.	Ground frog <sup>4</sup>	Medium	$\frac{1}{3}$ grain	Died.	15 minutes	Appearances normal.	
XLII.	"	"	$\frac{1}{3}$ "	"	13 "	Ditto.	
XLIII.	<i>Bufo galeatus</i>	Large	1 gr. dried venom.	"	27 $\frac{3}{4}$ hours	Wound slightly swollen and congested.	One grain freshly dried (without heat) venom was applied to wounded crural muscle through valvular cutaneous opening.
XLIV.	<i>B. melanostictus</i>	Very large.	1 $\frac{1}{2}$ grs. dried venom.	"	48 "	Wound softened and sloughing.	Applied as above.
XLV.	Ground frog	Largish	$\frac{1}{2}$ grain	"	32 minutes	Appearances normal.	
XLVI.	"	Medium	$\frac{5}{8}$ "	"	9 "	Ditto.	
XLVII.	<i>Polypedatus maculatus</i>	Large	$\frac{3}{4}$ "	"	28 "	.....	
XLVIII.	Ground frog	Medium	1 gr. dried venom.	"	85 "	.....	Applied as above.
XLIX.	<i>Polypedatus maculatus</i>	Large	$\frac{3}{4}$ grain	"	25 "	.....	
L.	<i>Bufo sp.</i>	"	1 $\frac{1}{2}$ grains	"	About 11 hours.	.....	
LI.	"	"	1 $\frac{1}{2}$ "	"	5 hours	.....	

<sup>1</sup> *loc. cit.*, pp. 68 and 70.

<sup>2</sup> *Proc. Roy. Soc.*, Vol. XXII (1874), p. 73.

<sup>3</sup> *loc. cit.*, p. 10 *et seq.*

<sup>4</sup> All the ground frogs used were of the same species—which I have not yet identified.

Fontana found<sup>1</sup> that from the viper-bite eels "die later" than "the other kinds of fish" he had experimented upon, and not until the end of 18 or 24 hours. Fayer reports<sup>2</sup> a case of a fish (*Ophiocephalus marulius*), 14 inches long, bitten near the tail by a cobra dying in 50 minutes.

On Fish.

Upon leeches<sup>3</sup> spermatozoa and infusoria, on many of the lower forms of plants<sup>4</sup> and on cell movement in *Vallisneria*, &c.,<sup>5</sup> snake-venoms have been found to have little or no toxic effect.

On Invertebrates and Plants.

### Part VI.—What is the Cause of the Serpents' Immunity from their Venom?

*How is the organism of the Venomous Snake able to resist the action of a chemical poison<sup>6</sup> which is fatal to most other animals?*

Having obtained information concerning the effect of venom upon several other species of snakes—venomous and non-venomous—and on various other animals, we are now in a better position for considering the difficult problem here presented.

The immunity is not to be explained upon the mere fact of the animal being cold-blooded. For, although venom acts *cæteris paribus* with greater force and rapidity on warm-blooded animals, and most so on those whose temperature is highest, *vis.* birds; yet, as we have seen, the other reptiles and other cold-blooded animals were affected by venom, and in several instances with a severity and rapidity little inferior to that exhibited by warm-blooded animals.

Fact of being cold-blooded.

Nor can the fact of having the anatomical conformation peculiar to ophidians explain the immunity. For, as we have seen, most, if not all, the non-venomous snakes are susceptible to venom. As Fontana long ago remarked (?) "if a comparison be instituted between two cold-blooded animals—one that dies of the disease of the venom, and the other that survives its action—they will be found to possess the same organs, the same circulation, an equal tenaciousness of life, and they will both of them appear perfectly alike . . . what is it then that causes the venom to be a poison to the one, and not to the other?"

<sup>1</sup> *loc. cit.*, p. 41.

<sup>2</sup> *loc. cit.*, p. 68.

<sup>3</sup> FONTANA *loc. cit.*, p. 35.

<sup>4</sup> MITCHELL, *loc. cit.*, p. 52. *Vide* also foot-note, p. 27.

<sup>5</sup> BRUNTON AND FAYRER, *loc. cit.*

<sup>6</sup> Snake-venom possesses all the characters of a strictly *chemical* poison as opposed to those of a *living* ferment or enzyme. Amongst the direct evidence on this head are the experiments by ALBERTONI and BUPALINI with the blood of envenomed animals (*Rivista di chimica Med., Farm.*, December 1883). And culture-experiments by Prof. FORMAD of Philadelphia in regard to *crotalus* venom (Mitchell and Reichert "Researches upon the Venoms of Poisonous Serpents" [Smithson. Contrib.], Washington, 1885, p. 137) and by Dr. WOLFENDEN in regard to cobra venom (*Ind. Med. Gaz.* 1885), gave negative results.

<sup>7</sup> *loc. cit.*, p. 276.

Neither does the mere possession of an active poison-apparatus secure immunity. For, as we have seen, cobra-venom proved rapidly fatal to the tree-vipers experimented upon.<sup>1</sup> And the *Dipsadæ*, which possess grooved fangs, and thus presumably related to the venomous snakes, were found<sup>2</sup> to be much more susceptible to venom than the relatively much smaller and wholly innocent *Simotes*.<sup>3</sup>

In what manner, then, is the immunity to be explained?

In answer to this I have at present only an hypothesis to offer: From what has gone before, it would appear that the venomous snake does not secure its immunity through any peculiarity in general structure or physiology *per se*; nor, does the mere possession of an active-poison apparatus render the snake immune to the venom of a more highly virulent species. The one striking feature, which is uniformly associated with the immunity, is the possession of a venom of a degree of virulence and other qualities special to the particular species;<sup>4</sup> and we have seen that snakes are habitually swallowing some of their own venom, and absorbing small quantities through wounds and abrasions within the buccal cavity. Under these circumstances, is it not possible that the immunity may be an acquired condition—a toleration to the venom established through frequent imbibition of small quantities of the venom in the modified or attenuated form which the venom assumes when mixed with salivary and gastric juices, and absorbed through the alimentary canal?<sup>5</sup>

<sup>1</sup> Implying that there are degrees of immunity.

<sup>2</sup> *Vide* Experiments 29, 30, and 32.

<sup>3</sup> *Vide* Experiments 26, 28, and 31.

<sup>4</sup> Regarding the probable inter-immunity of the Cobra and *Daboia*, *vide* pp. 17 and 19.

<sup>5</sup> MITCHELL and REICHERT, *loc. cit.*, p. 44, reviewing the published observations upon the absorption of venom by mucous surfaces, state that "the verdict of all observers in connection with the venom of the crotalidæ is that uninjured mucous surfaces, except in the lungs, cannot absorb venom, at least in sufficient quantities to produce death. In experiments with the venom of the cobra other investigators have gotten results which are directly contrary; but in our own researches (details of which are given) a large proportion of the animals survived." And experiments are given to show that "the gastric juices . . . are destructive of venoms."

On the *digestion* of cobra-venom I have the two following experiments:—

EXPERIMENT LII.—Of a solution of cobra-venom, of which 8 minims killed a chicken weighing 14 ounces in 14 minutes, 15 minims were taken, and to this were added 15 minims of a freshly prepared and faintly acid solution of *Pepsine* (10 grs. to oz. of water) of ascertained activity; and the mixture was digested for 20 hours at a temperature ranging between 83° to 90° Fah. The solution was then filtered, and the whole of the filtrate injected hypodermically into thigh of a chicken weighing 16 ozs. The chicken died in 70 minutes with all the symptoms of cobra-poisoning.

EXPERIMENT LIII.—Of the same solution of cobra-venom as was used in above experiment 10 minims were added to 20 minims of a freshly-prepared and faintly acid solution of *Papaine* (10 grs. to oz. of water) of ascertained activity; and the mixture digested for 21 hours at a temperature ranging between 83° to 90° Fah. The solution was then filtered, and the whole of the filtrate injected hypodermically into thigh of a chicken weighing 14 ozs. The chicken died in 58 minutes with symptoms of cobra-poisoning.

These experiments would tend to show that digestion modifies the virulence of cobra-venom: thus, of a solution of venom of which 8 minims killed a chicken weighing 14 ozs in 14 minutes, 15 minims (a slight loss would occur through filtration) when digested with pepsine failed to kill a chicken weighing 16 ozs. until 70 minutes; and 10 minims when digested with papaine failed to kill a chicken weighing 14 ozs. until 58 minutes.

In support of this hypothesis the following additional arguments may be

Additional arguments favouring adduced :  
hypothesis.

Injection of *purely chemical* material may, it is reported, procure immunity

Injection of *purely chemical*  
material alleged to procure immu-  
nity from specific disease.

from a specific disease: the protection conferred by 'vaccine' being, it is alleged, attributable, in certain cases, to the action of the soluble chemical

products resulting from the growth and development of the morbidic germ, rather than to any direct action of the fungus itself.<sup>1</sup>

Venom not a general protoplasm-  
poison.  
with cell life.

Venom is not a general protoplasm-poison,<sup>2</sup> so that its presence need not necessarily be incompatible

It is an established fact that cells may, by a process of education, become

Habituation of protoplasm to  
foreign food.

habituated to nutriment, which they at first reject when it is presented to them in a concentrated form.<sup>3</sup>

It is thus not impossible that the protoplasm of the snake may become gradually habituated to the presence of this extraneous proteid material—venom.

It has long been suspected that certain snake-charmers by a process of

Alleged practice of inoculation  
among snake-charmers.

inoculation with venom gain protection against the bite of a particular species of venomous snake.<sup>4</sup>

And this belief was not effectually disposed of by FAYRER'S experiments on the hurriedly prepared dogs submitted by him to snake-bite.<sup>5</sup>

<sup>1</sup> M. BOUCHARD and others have demonstrated (says the *Lancet*, 1888), that a rabbit may be protected against the pyocyanic disease by injecting under its skin the soluble products of cultures deprived of all microbes by heat and filtration; and that immunity can also be secured by injecting sterilized urine of rabbits dead from pyocyanic infection, and MM. Charrin and Ruffer (*France Med.* No. 126) find that the soluble products of artificial cultures are eliminated by the kidney without losing their power of conferring immunity. Dr. WOOLDRIDGE ("Note on Protection in Anthrax," *Proc. Roy. Soc.*, 1887, p. 313), found as regards anthrax that the albuminous culture-fluid freed from anthrax bacilli (and spores?) by filtration confers protection. Confirmation, however, of such experiments by KOCH or other thoroughly reliable observer is needed; as it is highly remarkable that strictly soluble material can make so very lasting an impression on the system.

<sup>2</sup> The evidence on this point is extensive, *vis.*—FONTANA'S experiments with viper-venom on leeches *l. c.* p. 36. MITCHELL'S experiments with *Crotalus*-venom on rotifers "and other forms of animalcular life, and on fungi, *loc. cit.* pp. 50—52. DARWIN'S experiment with cobra and adder-venom on *Drosera*,—"Insectivorous Plants" Lond., 1875, p. 206 *et seq.* BRUNTON and FAYRER'S experiments with cobra-venom on leucocytes, ciliary motion, cell-movement in *vallisneria*, and on germinating seeds, *Proc. Roy. Soc.*, 1875., p. 278, Vol. 23. MITCHELL and REICHERT'S experiments with rattlesnake-venom on ciliary movement, spermatozoa, &c., *loc. cit.*, p. 149 *et seq.* A. E. FEOKTISTOW'S experiments with venoms of *Vipera ammodytes*, *v. berus*, and *crotalus durissus* on spermatozoa, monads, and bacteria.—*Trans. Imp. Ac. Sci.* St. Petersburg, 1888, quoted in *Lancet*, p. 333, Vol. II, 1888.

<sup>3</sup> THISELTON-DYER in *Nature*, p. 480, 1888.

<sup>4</sup> A popular belief, shared by NICHOLSON, but apparently on mere conjecture (*loc. cit.*, p. 148); and by, if rightly remember, DR. STRADLING, but at present I am unable to refer to the published views of the latter.

<sup>5</sup> *Thanatophidia of India*.

This hypothesis would also lend itself to explain the relative or absolute protection possessed by one species of highly virulent snake against another highly venomous snake of a different genus or family (*e. g.* the *Daboia* against the Cobra). For, Mitchell and Reichert have shown<sup>1</sup> that the various serpent-venoms examined by them are mixtures of two or three proteids (*viz.* 'Venom-albumin,' 'v.-globulin,' and 'v.-peptone'); and that the venom of one species of snake differs from that of another, mainly, if not entirely, in the different proportions in which these constituent proteids are present. The *Daboia* and Cobra might, in this way, be regarded as being protected against each other<sup>2</sup> to that extent to which their venom contains a corresponding proteid, and thus have to contend against only a moiety of the poison.<sup>3</sup>

The hypothesis here put forward can readily be tested by experiment; and to this test I propose submitting it when opportunity offers.

<sup>1</sup> *loc. cit.* And Dr. WOLFENDEN has generally confirmed this observation as regards cobra-venom (*Ind. Med. Gaz.*, 1885).

<sup>2</sup> *Vide* p. 63.

<sup>3</sup> The venoms of the Cobra and *Daboia* appear to have much in common: "The general symptoms produced by the poison of the *Daboia* are nearly the same as by that of the *Naja*," BRUNTON AND FAYRER, *loc. cit.*, p. 68.

L. A. WADDELL, M.B.

SILLIGURI,

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