

THE DEVELOPMENT OF MOVEMENT
OF THE ALBINO RAT BEFORE BIRTH.

by

Engelbrekt A. Swenson

A. B. Bethany College, 1913.
A. M. University of Kansas, 1923.

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Swenson
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I. INTRODUCTION

So far as can be determined no one has described the prenatal development of movement of a mammal. This information is needed for correlated anatomical and physiological studies of the mammalian embryo and fetus. Moreover, it would add to the present extensive knowledge of mammalian behavior, and also assist in analysing the complex behavior of the adult mammal.

The albino rat is the animal of choice for such behavior study, for it is one of the best known of the common laboratory animals. Besides, it is a small mammal with a period of gestation which is short-- 21 to 22 days. The fetuses can be shelled out of the uterus and observed in a viable condition for sufficient length of time to make accurate observations.

Bichat in 1803, according to Preyer (1885) was probably the first to observe the fetal movements of the guinea pig. Züntz ('77) observed and studied the respiratory movements of a guinea pig.

Preyer in 1885 has given a rather extensive description of the behavior of the guinea pig, especially of the later stages of behavior. In short protocols he has described the heart beat of 8 embryos of the third week of gestation. In one of these

embryos, which measured 12.5 mm. in length, he noticed a doubtful movement of the trunk of the fetus. A study of 4 embryos of the 4th week of gestation was made, and in this stage he records the beginning of movement which was a vigorous movement of the trunk, though he noted it in only one of the 4 embryos. The size of the embryo in which movement occurred was 16 mm. A further description of the embryo was included in the sentence: "The toes are not yet separated." He has given us a very brief description of 18 embryos of the 5th week of gestation, 8 embryos of the 6th week, as well as a shorter description of 11 embryos of the 7th week and 22 of the 8th week.

His attentions were centered on the activity of the heart, respiration movements, and spontaneous movements. Preyer's observation of the movements of the chick embryo have been reviewed in part by E. L. and E. R. Clark ('14) as follows: "From the first to the fifth day of incubation he found no embryonic movements, aside from the beating of the heart. Mechanical and electrical stimulation of the embryo produced no effect. On the fifth day, Preyer first observed the active embryonic movements and the amniotic contractions. The first movements of the embryo, according to Preyer, are simple in character and consist chiefly in a bending of the back from side to

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side. The head, tail, and extremities are moved passively at this stage. In successive later stages, the movements become more numerous, violent and complicated, as the various parts of the embryo differentiate. At the sixth and seventh day, the bending of the body becomes more pronounced, the tail contracts independently, the head nods, and the paddle-like extremities are moved inward and outward, and from the eighth to the eleventh day, the movements continue to increase in strength and variety. Intervals occur at all these stages, during which the embryo does not move. During this second period of development--from the fifth to the eleventh day--Preyer found no response of the musculature to mechanical stimulation or to injury, such as amputation of a leg. However, he occasionally observed a weak response of certain muscles, following electrical stimulation of the spinal cord, on the ninth and tenth day of incubation.

"In the third stage of development described by Preyer--the period from the eleventh to the fifteenth day--the active movements of the embryo continue to occur, at frequent intervals, and, in addition to those present in younger chicks, movements of the individual toes and opening and closing of the eyelids and beak occur frequently. At this stage, reaction to mechanical stimulation is doubtful: at times a seemingly

definite response is obtained and, at other times, the embryo remains motionless when stimulated, although continuing to move spontaneously. At this stage, however, chicks responded definitely to electrical stimulation, by movements of the limbs, toes, beak, etc., according to the point at which the stimulus was applied.

"In the last period of development--from the sixteenth to the twentieth day of incubation, Preyer states that spontaneous movements are much less frequent, but that the chicks respond readily to electric stimulation by tetanic contraction, and show an increased tendency to respond reflexly to mechanical stimulation.

"With his especially constructed ooscope, Preyer was able to observe, at all stages, both types of embryonic movements, those due to the contractions of the amnion, and those due to contractions of the muscles of the embryo itself, in the unopened egg, kept at incubator temperature, thus proving that they are normal, and not caused by outside factors introduced at the time of opening the shell.

"Our observations of the muscular movements of chicks were confined to embryos of four to fourteen days, since this comprises the important periods in the development and early functioning of the lymph

heart. Our observations agree with Preyer's description of the character of these movements, and of their first appearance in chicks of four days. However, in addition to the movements of the various parts of the embryo, described by Preyer, we noticed that sudden violent jerks, which seemed to involve the entire musculature of the embryo, occurred at all of the stages studied. With regard to the absence of all reaction to mechanical stimulation, in chicks between the fifth and eleventh day, our results are in entire agreement with those of Preyer.

"One very striking characteristic of the active movements of chicks during the period of their development from four to fourteen days, is their periodicity. The movements occur in definite groups or spasms followed by an intermission or period of rest, after which the movements recur. This periodicity was not noted by Preyer or by earlier observers, although they record the fact that the active movements were not continuous."

Langworthy ('25) has studied the development of progression and posture in young opossums. He has given us a description of the behavior of 35 of these pouch-young opossums after decerebration. He notes that in the younger pouch-young opossums decerebrate rigidity is not evident following decerebration, but

the movements which follow decerebration are progression movements. However, in the older animals decerebrate rigidity predominates. Langworthy does not give us any such detailed account of the movements as have been recorded by Preyer and Clark for the chick. Hartman ('20) has observed the behavior of pouch-young opossums, and makes note that the opossum when born actually crawls by its own effort into the pouch of the mother.

The progression movements of four 8-cm. fetuses of a cat have been observed by Graham-Brown ('15). The movements and responses of 20 human fetuses have been recorded by Minkowski, particularly with reference to reflexes of clinical significance and concern rather early periods in development. These fetuses were removed by cesarean operation while the mother was under local anaesthesia of novocain and adrenalin. All but two of the fetuses suffered from asphyxia, as evidenced by the degree of cyanosis. His work, therefore, contributes very little to the problem of development of movement.

H. H. Lane ('17) has described the development of the special senses of the white rat. He finds that the special senses make their appearance in the following order: touch, equilibrium, smell, taste, hearing, and sight. Touch became evident in fetuses of 16 mm. C.R.L. to pricking with a needle on the snout, flanks, and back, and other parts of the body, but no

response to stroking with a fine sable brush, and the first movement was a movement of the "head as a whole" to one side. The first indication of equilibrium occurred in fetuses 35 mm. C.R.L. "One hour after their removal from the mothers' uterus they were able to sit upright on the belly with forepaws placed well apart and the head up." The first indication of smell in the fetus occurred after birth, so too with taste and sight.

The writer wishes to thank Dr. M. J. Greenman for the many courtesies extended to him during his stay at the Wistar Institute of Anatomy and Biology. The writer acknowledges his great indebtedness to the Wistar Institute of Anatomy and Biology for placing at his disposal materials and facilities which made this study possible. It is also a great pleasure to him to acknowledge the interest and assistance of Prof. G. E. Coghill, under whose guidance the work was done. Finally, the writer wishes to express his appreciation to Professor H. C. Tracy for his unfailing interest and encouragement.

II. EXPERIMENTAL PROCEDURE

The pregnant female rat is anesthetized with ether under an inverted 11-inch funnel. When the animal is sufficiently under the influence of the ether it is quickly and securely tied by all four feet, back down, to a wire frame. Ether is now administered by the drop method. A 35-mm. Gooch crucible, serving the purpose of a mask, is held in place over the snout of the rat by means of a strong thread stitched through the upper lip with the aid of a perforating needle, then tied; the other end of the thread is passed through one of the holes in the bottom of the crucible and then wound around the upright rod which is mounted on the wire frame for this purpose. With a sharp scalpel an incision is made in the median line through the skin of the neck from a point a little cephalad of the angle of the jaw to the sternum. The large glands of the neck, which cover the trachea and sternocleidomastoid muscles, are carefully dissected free from their fascial coverings and turned laterally. With two very smooth probes made of bone and sharpened to a point, the common carotid arteries are secured, each in turn carefully separated from the accompanying vago-sympathetic nerve and ligated with fine silk sewing thread as close to their origin as possible. The large right and left external jugular veins are se-

cured and ligated close to where they empty into the innominate veins. Ether is now discontinued for a while, and the skin incision quickly closed with a few stitches. The head of the rat is raised and extended by tightening and tying the strong thread, which was previously fastened to the upper lip, higher up on the upright rod.

The rat, made fast to the wire frame as described above, is transferred to the Pyrex glass dish where it is immersed in warm (37.5° C) Ringer's solution, care being taken to keep the nose and mouth above and out of the solution. The temperature of the Ringer's solution is maintained during the experiment practically constant at 37.5° C. by the following method. The Pyrex glass dish containing the Ringer's solution is lowered into a pan of tap water to a depth of two inches. The water in the pan is heated by means of an electric water heater which is equipped with a thermostat. The proper temperature is maintained by adjusting the thermostat before the experiment is started. The Pyrex glass dish used in these experiments is 5-1/2 inches wide, 10-1/2 inches long, and 3-1/2 inches deep.

Since the wire frame and rat are generally colder than the Ringer's solution, a little time must elapse before the temperature of the Ringer's solution is again constant at 37.5° C. The abdomen is then

opened with a sharp scalpel in the midline. The incision is made through the linea alba in order to avoid hemorrhage. The right and left horns are secured and lifted out of the peritoneal cavity. If the incision is not too large, the other viscera will not protrude through the incision. In case they do protrude, they can be pushed back into the peritoneal cavity and a recurrence of the protrusion prevented by packing against them loose balls of absorbent cotton.

With a pair of scissors small transverse slits are made in the uterus over each swelling; care being taken to avoid cutting the larger uterine blood vessels. The chorion with its contained fetus can be pressed out through the incision. If the slit is sufficiently small the placenta will not protrude. An incision is now made in the chorion with a pair of sharp iridectomy scissors, the amnion seized with the tissue forceps, slit open with the iridectomy scissors, and the fetus is exposed.

In order that the fetus may be more easily observed it is carefully placed in a small net, lowered into the Ringer's solution. These nets are made of fuse wire and paraffin-coated gauze. They are made fast by bending the pliable handle of the net over the edge of the Pyrex glass dish. The nets are very convenient; besides, they prevent undue stretching of the

umbilical cord. The exposed fetus as it lies in the net in the Ringer's solution may be stimulated and the movements observed or photographed.

By the time the first fetus is shelled out the mother rat generally is restless, and a few drops of ether should be applied to the mask. Very little ether is used, however, after the skin incision of the neck is closed, and none unless the rat moves. In this case two or three drops of ether are given, an amount sufficient to keep the mother rat calm for several minutes. After the first hour cerebral anemia, which has been induced by ligation of the common carotid arteries and external jugular veins, becomes effective and very little or no ether is needed for periods frequently as long as twenty, or occasionally forty, minutes.

All the observations were made on timed female albino rats from the colony at the Wistar Institute of Anatomy and Biology. The rats used were healthy and docile, which was of considerable advantage.

All metals--such as the wire frame-- were dipped into melted paraffin to insulate them and prevent action of the Ringer's solution from liberating electrolytes, which might cause stimulation or even injury to the fetus.

The Ringer's solution used consisted of:

Calcium chloride.....	0.2 gram
Potassium chloride.....	0.2 gram
Sodium chloride.....	9.0 gram
Distilled water.....	1000.0 cc.

In the past year and three months the writer has studied the movements of the fetus of the albino rat. The original plan was to study the behavior of the rat fetus from the time the first movement appeared until birth. It was soon evident, however, that this could not be done within the time limits that had been set, because of the rapid development and the growth of the fetus after the first movement appeared, which necessitated an intensive study at hourly intervals of many fetuses, especially between the 378th hour and the 408th hour. Therefore, the work was centered on this period of development. The movements of 117 fetuses from 26 litters have been observed, and a written record made of the responses to tactile stimulation and of spontaneous movements. Fetuses of 20 litters after the 408th hour have been studied and the movements recorded.

III. PROTOCOLSNon-motile stageRAT 40

Date of Insemination: Nov. 22, 1925, 3:42 P.M.

Date of Experiment: Dec. 12, 1925, 8:06 P.M.

Age at Beginning of Operation: 364 hours 24 minutes.

Fetus 1

Age at Beginning of Observation: 365 hours.

Time under Observation: 10 minutes.

C-R Length in Ringer's Solution: 12 mm.

8:37. Fetus 1 shelled out of the amnion. Stim-
P.M. ulated the snout, using the bristle, but no
response followed.

8:50. Have been stimulating the snout, mostly, and
the body, using the bristle, probe, and
needle, but I have been unable to cause a
response. C.R.L. in salt solution 12 mm.
Into Formalin.

Fetus 2

Age at Beginning of Observation: 365 hours.

Time under Observation: 16 minutes.

C-R Length in Ringer's Solution: 12 mm.

8:37. Fetus 2 shelled out of the uterus.
P.M.

8:52. Shelled out of the amnion.

- 9:01. Not a response to any kind of tactile stimulation. Mother rat lightly anesthetized. No spontaneous movements observed.
- 9:08. C.R.L. 12 mm. Into Bouin's.

Fetus 3

Age at Beginning of Observation: 365 hours 30 minutes.

Time under Observation: 7 minutes.

C-R Length in Ringer's Solution: 12 mm.

9:13. Not a sign of movement in Fetuses 3 to 6 as P.M. they lie in the amnion. Prodding them on snout and body failed to evoke a response.

9:15. Fetus 3 shelled out. No response.

9:22. No response. Used bristle, bone probe and divider point, which was cold. C.R.L. in salt solution 12 mm. Ruined Fetus 3. Dropped him into the tap water of the outside bath. These embryos are very delicate!

Fetus 4

Age at Beginning of Observation: 365 hours 30 minutes.

Time under Observation: 10 minutes.

C-R Length in Ringer's Solution: 12 mm.

8:37. Six embryos shelled out of the uterus. P.M.

9:13. Not a sign of movement in Fetuses 3 to 6 as they lie intact in the amnion. Prodding them

- on the snout and body failed to evoke a response.
- 9:30. The heart beats are rapid, almost too rapid to count. The heart can be seen as a red object pulsating as the embryo lies (contained) in the intact amnion. There is a thin film on the outside of the chorion and this was peeled off with the bone probe. This done, the embryos were more distinctly seen.
- 9:37. Not the slightest sign of movement except the rapid heart beat of the embryo F4 which is shelled out. C.R.L. in the salt solution 12 mm. plus.
- 9:40. Fetus 4 into Formalin. The mother is very lightly anesthetized. She is very calm. Her breathing is vigorous but not noisy, and has been so from the beginning.

Fetus 5

Age at Beginning of Observation: 366 hours.

Time under Observation: 13 minutes.

C-R Length in Ringer's Solution: 12 mm.

8:37. Six embryos shelled out of the uterus.
P.M.

9:52. Fetus 5 is still very much alive.

10:10. Changed the Ringer's Solution, partially, as

it was quite bloody. Fetus 5 heart beating rhythmically, too fast to count.

10:14. Fetus 5 shelled out nicely, but have failed to get any response or see any movement. The heart is beating characteristically, rapidly and vigorously, which surely indicates that the embryo is still alive and would move if it had the power of movement developed. No movements observed.

10:22. No response to any kind of stimulation using bristle, bone probe, and needle, and touching the snout and body.

This fetus is very pink.

C.R.L. in the salt solution 12 mm.

10:27. As yet no responses observed. The embryo still has a "good" appearance.

Cut out this embryo Fetus 5, as there are other fetuses to examine. Into formalin. There was no movement observed when the embryo Fetus 5 was dropped into the Formalin.

Fetus 6

Age at Beginning of Observation: 366 hours.

Time under Observation: 40 minutes.

C-R Length in Ringer's Solution: 12 mm.

8:37. Six embryos shelled out of the uterus.
P.M.

9:13. Not a sign of movement in Fetuses 3 to 6 as

they lie intact in the amnion, and prodding them on the snout and body failed to evoke a response.

9:52. Fetus 6 appears to be dead. This embryo is very pale. Still in the amnion.

Fetus 6 C.R.L. 12 mm.

Fetus 7

Age at Beginning of Observation: 366 hours 30 minutes.

Time under Observation: 10 minutes.

C-R Length in Ringer's Solution: 12 mm. minus.

10:37. Fetus 7 shelled out of the uterus and amnion.
P.M.

No movements observed in response to touch of the bristle on the snout or body region. No spontaneous movements observed. The heart beat is rhythmical and rapid.

10:43. No response to electrical stimulation using the inductorium and the interrupted current.

10:48. C.R.L. Fetus 7 12 mm. minus. Into Formalin.

The heart was pulsating rapidly when the embryo was cut away from the placenta. No movement was observed when the fetus was dropped into the formalin.

Fetus 8

Age at Beginning of Observation: 367 hours.

Time under Observation: 5 minutes.

C-R Length in Ringer's Solution: 12 mm.

10:50. Fetus 8 shelled out. No spontaneous movements
P.M.

or tactile responses observed.

C.R.L. 12 mm. in the salt solution,

10:55. No responses--no spontaneous movements observed. No movements of the embryo as it came in contact with the Bouin's Solution.

Fetus 9

Age at Beginning of Observation: 367 hours 30 minutes.

Time under Observation: 4 minutes.

C-R Length in Ringer's Solution: 12 mm.

10:57. The left horn of the uterus pulled out and
P.M.

there are two embryos in it. There were eight embryos in the right horn.

11:00. Fetus 9 shelled out of the uterus and the amnion.

11:04. Not the slightest response observed to tactile or electrical stimulation. No spontaneous movements. C.R.L. in the salt solution 12 mm.

11:06. Into Bouin's Solution. No movements observed when the embryo came into contact with the Bouin's.

Fetus 10

Age at Beginning of Observation: 367 hours 30 minutes.

Time under Observation: 12 minutes.

C-R Length in Ringer's Solution: 12 mm.

11:14. Shelled out Fetus 10. No movements observed.
P.M.

Constricted the trachea of the mother rat--
choking her. This caused the mother rat to
struggle for air. No movements of the
Fetus were observed.

C.R.L. of Fetus 10 12 mm. in salt solution.
Observed no movement as the embryo came into
contact with the Bouin's Solution.

11:20. No more fetuses. Killed the rat.

REMARKS

This experiment was carried through under
good conditions. The temperature was almost constant-
ly 37.5° C. and did not fluctuate more than 1/2 degree
at any time. The results, in my opinion, can be re-
lied upon, as everything was ideal and if the fetuses
were capable of movement they would have exhibited it.
There was no movement observed in any of the fetuses.
Very little ether was needed to keep the mother calm.
It was a satisfactory experiment.

RAT 32

Date of Insemination: Nov. 4, 1925, 4:32 P.M.

Date of Experiment: Nov. 20, 1925, 6:57 A.M.

Age at Beginning of Operation: 374 hours 25 minutes.

Fetus 1

Age at Beginning of Observation: 375 hours 3 minutes.

Time under Observation: 30 minutes.

C-R Length in Ringer's Solution: 13 mm.

7:30. Fetus 1 shelled out of the uterus.
A.M.

7:35. Shelled out of the amnion. No movement
observed.

8:02. Not a single response from Fetus 1.

8:05. Nearly dead. Heart pulsating very slowly
and the fetus is pale.

8:15. Cut out. C.R.L. 13 mm. Into Formalin.
No movements observed.

Fetus 2

Age at Beginning of Observation: 375 hours 15 minutes.

Time under Observation: 33 minutes.

C-R Length in Ringer's Solution: 13 mm.

7:30. Fetus 2 shelled out of the uterus. Still in
A.M. the amnion.

7:47. Shelled out of the amnion.

8:02. Not a single response from Fetus 2!

8:20. Fetus is dead. No response. Cut out.
C.R.L. 13 mm. Into Formalin.
No movements observed.

Fetus 3

Age at Beginning of Observation: 376 hours 8 minutes.

Time under Observation: 15 minutes.

C-R Length in Ringer's Solution: 13 mm.

7:30. Fetus 3 shelled out of the uterus, but still
A.M.

in the amnion.

8:25. Fetus 3 shelled out of the amnion. No
response.

8:40. Cut out. No response. Heart was not
beating. C.R.L. in the salt solution 13 mm.
Into Formalin.

No movements observed.

Fetus 5

Age at Beginning of Observation: 376 hours 22 minutes.

Time under Observation: 32 minutes.

C-R Length in Ringer's Solution: 13 mm.

8:54. Shelled out from the amnion. No responses.
A.M.

9:07. Tried electrical stimulation, using induc-
torium and rather strong interrupted cur-
rent, but no response could be evoked.
Fetus is pink in color. Heart beat rapid
and rhythmic.

9:15. Heart beat much slower now, but it is
rhythmic. Temperature of the bath 37° C.
and has been throughout the experiment ex-

periment except at the beginning it was
38° C.

- 9:20. No response.
- 9:25. Heart beat slow. Mother rat has been very
lightly anesthetized with ether. C.R.L. of
Fetus 5 13 mm., possibly a little less.
- 9:35. Cut out. Into Bouin's Solution.
No movements observed.

Fetus 6

Age at Beginning of Observation: 377 hours 22 minutes.

Time under Observation: 43 minutes.

C-R Length in Ringer's Solution: 13 mm.

- 9:45. Bubbled oxygen into the Ringer's solution.
A.M.
- 9:54. Fetus 6 shelled out of the uterus, but still
in the amnion. Have observed no movement
although the fetus has been under observation
for more than ten minutes.
- 10:03. No response.
- 10:20. No movement. Fetus 6 still in the amnion.
Prodded the fetus with the bone probe and
the bristle, but no response could be
evoked.
- 10:37. Fetus 6 is dead. Cut out. C.R.L. in
salt solution 13 mm. Bouin's solution.
No movements observed.

Fetus 7

Age at Beginning of Observation: 377 hours 22 minutes.

Time under Observation: 45 minutes.

C-R Length in Ringer's Solution: 13 mm.

9:45. Bubbled oxygen into the solution.

A.M.

9:54. Have shelled out of the uterus Fetus 7, but it is still in the amnion. No movements observed.

10:03. No response or movement.

10:20. No movement. Fetus is in the amnion.

Prodded with the bone probe and bristle, but could evoke no response.

11:05. Fetus 7 dead. Cut out. C.R.L. in salt solution 13 mm. Into Formalin.

No movements observed.

PROTOCOLSEarly motile stageRAT 32

Date of Insemination: Nov. 4, 1925, 4:32 P.M.

Date of Experiment: Nov. 20, 1925, 6:57 A.M.

Age at Beginning of Operation: 374 hours, 25 minutes.

Fetus 8

Age at Beginning of Observation: 378 hours 18 minutes.

Time under Observation: 24 minutes.

C-R Length in Ringer's Solution: 13.5 mm.

10:50. Shelled out Fetus 8 from the uterus and
A.M. amnion. Touched the snout of the fetus
many times with the bone probe and succeeded
in evoking only two faint or feeble "lateral
flexion of the head" movements.

11:14. Stimulated Fetus 8 with the interrupted in-
duction current. A feeble contraction oc-
curred. No contraction with a single make-
or-break shock from the inductorium.

11:20. No response from Fetus 8. Heart beating
slowly. Into Bouin's Solution.

Fetus 9

Age at Beginning of Observation: 379 hours 8 minutes.

Time under Observation: 20 minutes.

C-R Length in Ringer's Solution: 13.5 mm.

11:40. Shelled out Fetus 9 and a definite response
A.M. occurred when bristle was stroked over the
snout. It was a head movement to the left
side followed by a backward movement of the
right front limb.

With the bone probe got a single head move-
ment. Do not know which side was touched.

11:55. No responses from Fetus 9. Temperature of
the bath 38° C.

12:00. Cut out Fetus 9 into Formalin.

Fetus 10

Age at Beginning of Observation: 380 hours 15 minutes.

Time under Observation: 5 minutes.

C-R Length in Ringer's Solution: 13.5 mm.

12:07. Have shelled out and stimulated snout of
P.M. Fetus 10. Evoked a feeble response, move-
ment of the head to the side--used the
bristle.

Fetus lost too much blood from the cut
vessels of the chorion.

12:11. No more fetuses to observe. Killed the
mother rat.

RAT 24

Date of Insemination: Oct. 7, 1925, 4:35 P.M.

Date of Experiment: Oct. 23, 1925, 10:27 A.M.

Age at Beginning of Operation: 377 hours 52 minutes.

Fetus 1

Age at Beginning of Observation: 378 hours 32 minutes.

Time under Observation: 43 minutes.

C-R Length in Ringer's Solution: 13.5 mm. plus.

10:57. Fetus 1 shelled out of the uterus; still in
A.M. the amnion.

11:07. Head to the right. This was a spontaneous movement. When touched on the snout with the bone probe the head moved to the right. Movement to the right if touched on the left side of the snout and to the left if the right side of snout was touched. Have observed this head movement six times. Once the movement was to the same side touched. With the bristle the response was observed three times and in each case the movement was to the side touched. The movement is a movement of the head and neck region as a whole. There are no sensory areas other than the snout.

11:50. Fetus 1 shelled out of the amnion. Have noticed no movements of any kind. Fetus 1 is pale.

11:56. Cut out Fetus 1. Heart was beating feebly.

Fetus 5

Age at Beginning of Observation: 379 hours 15 minutes.

Time under Observation: 5 minutes.

C-R Length in Ringer's Solution: 14 mm.

12:30. Shelled out Fetus 5 and stimulated the snout
P.M. with the bristle and the response was a movement of the head as a whole and away from the side touched.

12:36. Due to the movements of the mother rat this fetus is dead.

Fetus 6

Age at Beginning of Observation: 379 hours 25 minutes.

Time under Observation: 38 minutes.

C-R Length in Ringer's Solution: 14 mm.

12:40. This fetus shelled out and the response to
P.M. stimulation with the bristle on the snout was a head movement away from the side touched. Five responses observed.

12:48. Again a response to bristle on the snout.

12:50. Again a response to bristle on the snout.

1:02. No responses now. No spontaneous movements observed. It seems that the umbilical cord became twisted and constricted.

1:18. Fetus 6 into Formalin.

RAT 27

Date of Insemination: Oct. 13, 1925, 3:50 P.M.

Date of Experiment: Oct. 29, 1925, 10:30 A.M.

Age at Beginning of Operation: 378 hours 40 minutes.

Fetus 1

Age at Beginning of Observation: 379 hours, 4 minutes,

Time under Observation: 1 hour 40 minutes.

C-R Length in Ringer's Solution: 13.5 mm. early, 14 mm.
late measurement.

10:54. Fetus 1 shelled out of the amnion. I stim-
A.M. ulated the right side of the snout with the
bristle and feeble movements of the right fore-
limb were observed.

11:05. Three spontaneous movements of the head, that
is, lateral flexion of the trunk, have been
observed. They occurred after a little ether
(4 drops) had been applied on the mask.

11:10. Stimulated the snout with the bristle and a
feeble and slow unilateral trunk contraction
occurred. Spontaneous movement noted. Again
spontaneous movement observed. Stimulated
the snout with the bristle and the response was
a feeble lateral flexion of the trunk and
movement of the head to the side.

11:20. With an upward stroke of the bristle on the
snout three responses consisting of lateral
flexion of the trunk were evoked. During
the movement the tail exhibited lateral
"lashing" movement.

- 1:21. Spontaneous movements observed.
- 1:30. Succeeded in evoking by means of tactile stimulation of the snout, using bristle, a rather vigorous unilateral flexion movement of the trunk with backward and forward movement of the left front limb.
- 1:31. Four lateral flexion of the trunk movements involving forelimb movement as well have been observed and were in response to upward stroke of the bristle on the snout. Again three lateral trunk movements evoked. In one case it was on both sides, alternate lateral flexion of the trunk. Fetus 1, 13.5 mm. in salt solution.
- 1:43. A vigorous bristle, snout response: left, right, left lateral flexion of trunk.
- 1:47. A slow but firm right and left side lateral flexion of the trunk movement. This was a spontaneous movement, and followed ether to the mother rat (1/2 minute after).
- 1:50. Again a bristle to snout response; lateral trunk movement left and right, firm but slow.
- 1:52. A single lateral flexion of the trunk movement to one side. Bristle touched to the snout.
- 2:15. Fetus 1 responded very feebly to touch of

bristle on the snout.

12:34. Cut out Fetus 1. C.R.L. 14 mm. in salt solution. Did not respond when it was cut out. Into Bouin's.

Fetus 2

Age at Beginning of Observation: 380 hours 6 minutes.

Time under Observation: 39 minutes.

C-R Length in Ringer's Solution: 14 mm. late measurement.

10:54. Have shelled out Fetus 2 from the uterus, but A.M.

it is still in the amnion.

11:56. Shelled the fetus out of the amnion.

12:02. Three vigorous lateral flexion movements of the trunk which were seen from the back, evoked by tactile stimulation of the snout using the bristle.

12:10. Have seen two more pronounced lateral flexion of trunk movements. There was a quickness or "jerk" to the movements. The rump showed some movement as well. Again the right-left-right, or alternate lateral flexion of the trunk with the same quickness present, and the right front limb seems to move forward and backward.

12:16. Spontaneous movement observed. Alternate lateral flexion of the trunk left, right, left, also movement of the right forelimb.

12:20. Five definite responses to tactile stimula-

tion of the snout, using the bristle and touching lightly, and these movements were lateral flexion of the trunk with movement of the head to the side opposite that touched and forward and backward movement of the forelimb.

- 12:25. A spontaneous lateral trunk movement is occurring in Fetus 2. The right forelimb is "waving".
- 12:28. Stimulation of the right side of the snout evoked an immediate lateral flexion of the trunk to the left--rather vigorous--the right forelimb waving.
- 12:38. Several definite spontaneous movements observed which consisted of alternate lateral trunk movements periodically emphasized by "quicker" lateral trunk movements. More spontaneous movement is occurring.
- 12:42. Stimulation of the left side of the snout evoked three lateral flexion movements of the trunk with movements of the head to the right and movement backward and forward of the left front limb.
- 12:45. Stimulation of the right side of the snout evoked a response of the head to the left with forward movement of the right front limb.

- 12:52. No responses now from Fetus 2.
- 1:00. Mother breathing noisily; uterus blue. Cut out Fetus 2. 14 mm. C.R.L. in salt solution. Into Formalin.
- 1:01. Mother rat dead.

RAT 48

Date of Insemination: Dec. 29, 1925, 4:20 P.M.
 Date of Experiment: Jan. 14, 1926, 12:21 P.M.
 Age at Beginning of Operation: 380 hours 1 minute.

Fetus 1

Age at Beginning of Observation: 381 hours 9 minutes.

Time under Observation: 29 minutes.

C-R Length in Ringer's Solution: 14 mm.

1:06. Shelled out of the uterus.
 P.M.

1:30. Fetus shelled out of amnion. Touched the left side of the snout of the fetus with the bristle and the response was a feeble lateral flexion of the head to the right side with feeble abduction of the left forelimb as a whole. Again a response; another response; but they are certainly very feeble!

1:52. No more responses; no movement despite stimulation. The movements recorded above were lateral flexion movements of the head away

from the side touched; there was also at the same time feeble abduction backward and forward movement of the left forelimb.

- 1:57. Heart beating much slower.
- 1:59. Held the umbilical vessels tightly with the tissue forceps for one minute, but no movements occurred. This fetus is still pink but will not respond.
- 2:02. C.R.L. in salt solution 14 mm. Ligated the umbilical cord and cut the fetus out. Into Bouin's.

Fetus 4

Age at Beginning of Observation: 381 hours 59 minutes.

Time under Observation: 48 minutes.

C-R Length in Ringer's Solution: 14 mm.

- 1:06. Fetus 4 shelled out of the uterus but still
P.M. in the amnion.
- 2:20. Fetus 4 shelled out of the amnion. Prodded the fetus, using the bone probe, on the left side of the snout and each time there was definite same side lateral flexion of the head. On the fifth prod there occurred a lateral flexion of the head to the right side with definite but feeble movement of the forelimb.
- 2:35. Have stimulated Fetus 4 with bristle to right

and left sides of snout and have seen twenty lateral flexion movements of the head. More often they were away from the side touched than toward, but not always. Spontaneous movements, ten or even more, and consisting of unilateral flexion movement of the head, were seen. Alternate lateral flexion movements have not been seen even though the contractions observed were of the right and left sides. There was always a little rest period between the unilateral flexion movements.

- 2:39. Touched the left side of the snout of the fetus with the bristle and the response was a lateral flexion of the head to the right side. Again the left side of the snout was touched, but this time the response was a lateral flexion of the head to the left side, and was followed by a more vigorous lateral flexion to the right side, with easily distinguishable forelimb (left) backward and forward movement.
- 2:45. Touching with the bristle, lightly, at a region just caudal to the shoulder or the forelimb and on the back over the spinal cord, a little to the right or left side of it, will evoke, sometimes, lateral flexion, even

alternate lateral flexion of the head, but more often lateral flexion of the trunk. This fetus has been very reactive to tactile stimulation and also spontaneously active. Tactile stimulation with the probe, bristle and at times the hair will evoke occasional lateral flexion movements of the trunk and head. And the movement is nearly always away from the side touched. Accompanying this lateral flexion of the trunk and the head is backward (abduction) movement of the forelimb, especially of the forelimb of the same side touched. The contraction is most pronounced in the region just at the level of the forelimb. Sometimes the contraction may be quick, at other times it is slow.

3:08. C.R.L. Fetus 4 in salt solution 14 mm.

3:11. Into Bouin's Solution.

Clamping the umbilical vessels with the tissue forceps caused in a very short time (8 seconds about) movements to occur. These movements were three alternate (left-right-left) lateral flexion movements of the trunk mainly, the head moving but not as much as the trunk, but the contraction was of the trunk, and with these movements were noted abduction and back-

ward and forward movements of the forelimbs as a whole. Independent forelimb movements without any visible lateral flexion of the trunk were also observed.

Clamping the veins of the umbilical cord seemed to bring about movement as quickly as clamping the whole umbilical cord. Clamping the artery alone, however, did cause movement eventually, but it took much longer for the movement to appear. Clamping the umbilical cord, as described above, did not kill this fetus, nor was there any indication of gross damage to the vessels.

Fetus 6

Age at Beginning of Observation: 383 hours 3 minutes.

Time under Observation: 27 minutes.

C-R Length in Ringer's Solution: 14 mm. late measurement.

3:21. Fetus 6 shelled out of the uterus.
P.M.

3:23. Fetus 6 shelled out of the amnion. C.R.L.
13 mm.

3:36. Temperature of the bath 37.80 C. Tactile stimulation of the snout with probe and bristle evokes nearly always, provided there are intervals of rest after three or four responses,

lateral flexion of the head and trunk with the forelimb as a whole moving backward and forward one or two times. Alternate lateral flexion of the head and trunk occurred only two times as a follow-up of the tactile stimulation of the snout and the probe was used to stimulate.

Clamping the umbilical cord quickly brought on (before I could count to ten) alternate lateral flexion of the head and trunk with forelimb abduction and backward movements, and this was repeated three times. Clamping the veins, which are scarlet in color, does the same thing. The arteries, which are darker red, the same, but it takes longer for the movements to occur. The fetus seems to recover from this clamping off of the bloodvessels. This shows that the fetus does react to changes in the blood. Is it lack of oxygen or increase of CO_2 or is it both, or are there other factors which cause the movements to occur when the umbilical vessels are clamped by means of the tissue forceps?

3:50. Fetus 6, C.R.L. 14 mm. late measurement in salt solution. Into Bouin's Solution.

RAT 70

Date of Insemination: March 22, 1926, 3:03 P.M.

Date of Experiment: April 7, 1926, 1:45 P.M.

Age at Beginning of Operation: 382 hours 42 minutes.

Fetus 1

Age at Beginning of Observation: 383 hours 12 minutes.

Time under Observation: 23 minutes.

C-R Length in Ringer's Solution: 13.5 mm. plus

2:02. Temperature of the bath, 37° C.
P.M.

2:08. Uterus exposed. Temperature of the bath 36.5°
C. Fetus 1 shelled out of the uterus.

2:15. Fetus 1 shelled out of the choramnion.

2:16. Touched snout, right side, five times. No
responses. Touched left side of the snout
five times. No responses.

2:19. Touched the left side of the snout of Fetus 1.
Feeble lateral flexion of head to the right.
Again same response, very feeble!

2:27. Spontaneous lateral flexion movements of the
head.

2:28. Touched the right side of the snout of Fetus 1.
Feeble unilateral flexion of the head. Touched
the left side. Feeble unilateral flexion of
the head to the right, feeble backward movement
of the right front limb. Spontaneous move-
ments observed.

2:29. No response when touched with bristle over flanks,

and back.

- 2:31. Clamped the umbilical cord with tissue forceps. No response after 1 minute. Touched the right side of the snout of fetus with bristle; feeble unilateral flexion of the head to the left with feeble backward movement of the right forelimb.
- 2:36. Fetus 1, C.R.L. 13.5 mm. to 14 mm.
- 2:38. Fetus 1 umbilical cord ligated. No movements followed after three-quarters of a minute.
- 2:39. Into Bouin's Solution.

Fetus 2

Age at Beginning of Observation: 383 hours 14 minutes.

Time under Observation: 24 minutes.

C-R Length in Ringer's Solution: 13.5 mm.

2:02. Temperature of the bath 37° C.
P.M.

2:08. Uterus exposed. Temperature of the bath 36.5° C.

2:09. Fetus 2 shelled out of the uterus.

2:17. Fetus 2 shelled out of the choramnion.

2:18. Touched right side of snout of fetus 2 five times. No response. Touched left side of snout of fetus 2 five times. No response. Touched the left side of snout of Fetus 2. Questionable feeble forelimb movements.

- 2:21. Touched the right side of snout of Fetus 2 five times. On third touch very feeble lateral flexion of the head with abduction of forelimb. Touching the right side of the snout, passive forelimb movement, unilateral flexion of head; better response.
- 2:22. Touched left side of snout. No response. Stroked three times over shoulder, left side, with bristle. No response.
- 2:23. Spontaneous movement: unilateral flexion of head with passive abduction of the left forelimb.
- 2:24. Touched left side of snout with bristle, lightly; unilateral flexion of the head to the right side with backward abduction movement of the left forelimb. Again same response. Again same response. Touched right side of snout and the response was a feeble but definite lateral flexion of the head to the left with backward movement of the right front limb. No movement of the hindlimb.
- 2:30. Fetus 2 stroked with bristle over back. No response. Spontaneous movements observed; lateral flexion of the head to the right with backward and forward movement of the left

- forelimb. The movement was feeble. Touched the left side of the snout of fetus 2, lightly, response was lateral flexion of the head to the right, backward abduction of the forelimb of the left side.
- 2:31. Touched the left side of the snout. Response was lateral flexion of the head to the right with backward abduction movement of the left forelimb, feeble.
- 2:33. Clamped umbilical cord with tissue forceps. No movement immediately. After a quarter of minute feeble movements of the left front limb observed, abduction backward. Heart is beating vigorously.
- 2:34. Touched the right side of the snout; response was lateral flexion of the head to the left with backward movement of the right forelimb. No hindlimb movement observed in either fetus 1 or fetus 2. Another response, unilateral flexion of the head.
- 2:36. C.R.L. 13-1/2 mm. in salt solution.
- 2:41. Umbilical cord ligated. No movements followed after 1 minute. Heart is beating vigorously.
- 2:43. Cut out into Formalin.

Fetus 3

Age at Beginning of Observation: 383 hours.

Time under Observation: 34 minutes in amnion;
8 minutes shelled out.

C-R Length in Ringer's Solution: 14 mm.

2:06. Temperature of the bath, 37° C.
P.M.

2:08. Uterus exposed. Temperature of the bath
36.5° C.

2:10. Fetus 3 shelled out of the uterus.

2:44. Shelled out of the amnion.

2:45. Touched the right side of the snout with
bristle, lightly; unilateral flexion of
the head to the left, backward passive move-
ments of the right front limb. Temperature
of bath, 36.5° C. Touched right side of
snout, single unilateral flexion of the head
to the left. Stroked the back with bristle,
lightly, response was lateral flexion of the
head with backward movement of the right fore-
limb. Again no response. Third stroke,
response. Touched right side of snout of
fetus, no response. Touched the right side
of the snout of the fetus with the bristle;
lateral flexion of the head and trunk with
backward forelimb movement and questionable
abduction of the hindlimbs. Touched the
left side of the snout, lightly; response
was lateral flexion of the head to the right

with feeble backward movement of the left forelimb.

- 2:50. Touched the side, region of the shoulder, lightly; response was feeble but definite backward movement of the left forelimb. Touched in region of shoulder, lightly, with bristle; response was lateral flexion of the head to the left. Touched the left side of the snout of the fetus lightly three times; response was lateral flexion of the head to the right, or lateral flexion of the trunk to the right. Again same response.
- 2:51. Touched left shoulder with bristle; backward movement of the left front limb, feeble!
- 2:52. Ligated umbilical cord. No movements followed. Fetus 3 cut out. Into Bouin's Solution. C.R.L. in salt solution 14 mm.

Fetus 4

Age at Beginning of Observation: 383 hours.

Time under Observation: 46 minutes in amnion;
13 minutes shelled out.

C-R Length in Ringer's Solution: 13.5 mm.

2:02. Temperature of the bath, 37° C.
P.M.

2:08. Uterus exposed. Temperature of the bath
36.5° C.

- 2:11. Fetus 4 shelled out of the uterus.
- 2:57. Fetus 4 shelled out of the amnion. Touched bristle to left side of snout; a definite response, unilateral flexion of the head and trunk to the right with backward movement of the left forelimb, occurred. No movements of the hindlimb. Again same response. Bristle to left side of snout. Touched right side of snout; lateral flexion of the head and trunk to the left with backward movement of the right forelimb. Bristle stroked over shoulder three times; no response.
- 3:00. Touched the right side of the snout of the fetus; lateral flexion of the head, passive backward movement of the right forelimb. Temperature of the bath 37° C. Touched the right side of the snout of the fetus; response was lateral flexion of the head and trunk to the right with feeble backward movement of the right forelimb.
- 3:02. Turned fetus over. Abduction of the forelimb with lateral flexion of the head to the right when left side of snout was touched lightly with bristle. Again same response. Again same response; bristle touched to the right side of snout.

- 3:04. Stroked over the right shoulder six times with bristle. Response was unilateral flexion of the head to the right. Spontaneous movements noted. Stroked over the shoulder and flanks; using the bristle; feeble forelimb movements of the side stroked.
- 3:07. Ligated umbilical cord. No movements observed. C.R.L. 13.5 mm.
- 3:10. Cut out fetus; into Formalin.

RAT 71

Date of Insemination: April 8, 1926, 2:11 P.M.
Date of Experiment: April 24, 1926, 2:22 P.M.
Age at Beginning of Operation: 384 hours 11 minutes.

Fetus 1

Age at Beginning of Observation: 384 hours 36 minutes.

Time under Observation: 39 minutes.

C-R Length in Ringer's Solution: 13.5 mm. plus.

- 2:47. Fetuses 1 and 2 shelled out from the right P.M. horn of the uterus.
- 2:51. Fetus 1 shelled out of the choramnion.
- 2:52. Touched left side of snout of the fetus with bristle and the response was an unilateral flexion of the head to the right. Again touched left side of snout of the fetus with

- bristle; movement was of the left forelimb.
- 2:54. Bristle to the right side of the snout and the response was unilateral flexion of the head to the left and then followed by backward movement of the left front limb. Have noted several unilateral flexion movements of the head away-from side of snout touched using the bristle.
- 2:57. Touched the right side of the snout of the fetus with bristle and the response was a definite or vigorous unilateral flexion of the head to the left. The trunk was involved in this movement and the movement was followed by backward movement of the left forelimb.
- 2:58. Bristle to the left side of the snout and the response was unilateral flexion of the head followed by alternate lateral flexion of the head and trunk and with this movement was backward movement of the forelimb. Again the right-left-right alternate lateral flexion with backward movement of the right and left forelimbs, and also movement of abduction of the hindlimbs. This was the response to the bristle touched to the left side of the snout. The forelimb and hindlimb movements are movements of the limb as a whole.

- 3:02. Observed spontaneous right-left-right lateral flexions with forelimb backward and hindlimb abduction movements. Again; the movement seemed to begin in the left forelimb, then pass to the trunk, then to the hindlimb. No response when the fetus was touched with the bristle over skin areas other than the snout.
- 3:09. The forelimb moves after the trunk or head unilateral flexion and the movement is abduction and backward and forward.
- 3:12. Clamped the umbilical vessel with the tissue forceps; counted to 9 and then there occurred a right-left-right lateral flexion of the trunk and head with the usual characteristic backward and forward movements of the forelimb. Touched with the bristle the left side of the snout of the fetus and the response was an unilateral flexion of the head to the right. Again clamped the umbilical cord; counted to 17 before an unilateral flexion of the right side of the trunk and head occurred. With these movements there was also backward abduction and forward movement of the forelimb.
- 3:20. C.R.L. in salt solution 13.5 mm. plus, but not 14 mm. Noted a right-left contraction of the trunk and head. All of the movements were slow.

- 3:26. Ligated the umbilical cord and vessels. No movements followed.
- 3:27. Into Bouin's Solution.

RAT 34

Date of Insemination: Nov. 13, 1925, 3:55 P.M.

Date of Experiment: Nov. 29, 1925, 4:57 P.M.

Age at Beginning of Operation: 385 hours 2 minutes.

Fetus 1

Age at Beginning of Observation: 385 hours 34 minutes.

Time under Observation: 54 minutes.

C-R Length in Ringer's Solution: 14 mm.

- 5:22. Shelled out of the uterus.
P.M.
- 5:27. Shelled out of the amnion.
Touched the snout of the fetus with the bristle and the response was a vigorous lateral flexion of the head to the right side.
- 5:30. No response even after much stimulation.
- 5:32. Feeble lateral flexion of the head and the forelimbs moving feebly. I probably pierced the skin of the snout with the bristle.
- 5:36. Touched the snout of the fetus with the flat side of the blade of the iridectomy scissors

- and the response was abduction of the right forelimb--slow but pronounced.
- 5:40. A vigorous response which was lateral flexion of the head and away from the side of snout touched; used the bone probe. Touched the shoulder with the bone probe and trunk lateral flexion of the same side occurred and this was immediately followed by lateral flexion of the other side of the trunk.
- 5:45. Using the bone probe and stroking the snout have observed ten away-from responses--lateral flexion of the head--they were associated with abduction of the forelimb as a whole.
- 5:48. Response to bristle to snout was two abduction movements of the right forelimb.
- 5:52. Vigorous lateral flexion of the head with choreic forelimb movements especially when the flat side of the bone probe is passed transversely over the mouth space and these movements are only to one side, never alternating.
- 6:06. Snout touched with the bone probe evoked response.
- 6:21. Fetus still alive--heart beating. Cut out. C.R.L. in salt solution 14 mm. Into Bouin's Solution.

Fetus 5 ³⁹

Age at Beginning of Observation: 386 hours 59 minutes.

Time under Observation: 30 minutes.

C-R Length in Ringer's Solution: 13.5 mm. plus.

5:22. Shelled out of the uterus.

P.M.

6:54. Noted spontaneous movements of this fetus while it was in the unopened amnion and as it was held in the net close to the surface of the solution. It was a movement of the head and the rump described an arc when seen from in front. (The fetus on the back.) The left forelimb abducted and waved choreic-like. Apparently the snout does not change position. The only spontaneous movement observed so far. Temperature of the bath 37° C. No ether to mother rat since 6:14 P.M., yet she has been calm.

7:01. Ether to rat. Disturbed!

7:13. Fetus 5 has been shelled out since 6:03 P.M. No responses observed despite much stimulation with the bristle.

7:24. Cut away Fetus 5. C.R.L. 13.5 plus in salt solution. Into Bouin's.

Fetus 7

Age at Beginning of Observation: 387 hours 33 minutes.

Time under Observation: 18 minutes.

C-R Length in Ringer's Solution: 13.5 mm.

- 7:27. I pulled out the other horn of the uterus;
P.M. there are five fetuses in it.
- 7:30. Shelled out Fetus 7; while the fetus was in the amnion observed three spontaneous unilateral flexion movements of the head to the right--the contraction occurred in the neck region--accompanying the head movement were "waving" abduction movements of the forelimbs. Turned the fetus over so that it faced toward me and observed a definite unilateral flexion of the head. The contraction was at the forelimb level and the movement was to the left side. Later I shelled out the fetus and obtained three definite, away-from lateral flexion movements of the head. Bristle touched to the snout.
- 7:40. Noted a vigorous response, away-from lateral flexion movement of the head--bone probe touched to the left side of the snout of the fetus.
- 7:46. Mother rat restless. Ether (4 drops) applied to the mask.
- 7:48. Cut out Fetus 7; still living. C.R.L. in salt solution 13.5 mm. Into Formalin.
- 7:52. Temperature of the bath 38° C.

RAT 38

Date of Insemination: Nov. 23, 1925, 3:17 P.M.

Date of Experiment: Dec. 9, 1925, 7:17 P.M.

Age at Beginning of Operation: 388 hours.

Fetus 1

Age at Beginning of Observation: 388 hours 30 minutes.

Time under Observation: 30 minutes.

C-R Length in Ringer's Solution: 14 mm.

7:45. Shelled out of the uterus and amnion.
P.M.

Have stimulated Fetus 1 many times, with the bristle and the bone probe and the response is always a lateral flexion of the head away from the side touched, if the snout of the fetus is stimulated. Nowhere else can a response be evoked. If the right or left paw is "bent back" by the bristle or bone probe then on releasing it may flex or bend at elbow. The front limbs do move a little when the lateral flexion of the head occurs. It seems that the front limb of the opposite side from that in which contraction occurs is moved backward as a whole. At least, there is front limb movement even though it is feeble. The lateral flexion of the head movements are only of one side, then rest! Fetus 1 has a large blood clot on the crown

7:45?

of his head!

8:13. The last response of this fetus was a lateral flexion of the head probably involving the trunk of the same side. It was a vigorous contraction. Spontaneous lateral flexion head movements were observed three times. They were weak, and so were the movements in response to tactile stimulation except the last one. The movements were of the left and right sides.

8:20. Fetus 1 C.R.L. in salt solution 14 mm. Alive when cut out.

8:22. Into Bouin's Solution.

8:24. Temperature of bath $37-1/4^{\circ}$ C.

Fetus 2

Age at Beginning of Observation: 389 hours 16 minutes.

Time under Observation: 48 minutes in amnion;
38 minutes shelled out.

C-R Length in Ringer's Solution: 14 mm.

7:45. Fetus 2 shelled out of the uterus, still in P.M.
the amnion.

8:33. Fetus 2 shelled out of the amnion. Obtained seven definite but slow "contralateral" flexion movements of the head with feeble, but definite, backward movements of the forelimb of the side touched when the snout was stimulated.

- 8:38. Stimulated the right side of the snout using the bone probe and the response was a contralateral flexion of the head with decided backward movement of the right forelimb which was followed by a flexion of the head to the right.
- 8:44. Fetus 2 is easily aroused and with the bone probe I have succeeded in arousing the contralateral flexion movements of the head with backward first, then forward movement of the forelimb of the same side touched.
- 8:47. Three spontaneous movements observed, as seen from the dorsal side. They consisted of lateral flexion of the head to the left, right and left.
- 8:50. Noted several spontaneous movements of the head and trunk lateral flexion movements, also feeble abduction of the hindlimbs. The latter were seen when the fetus was in the "standing on its head" position.
- 8:52. Employing the bristle and the human hair, touched the snout and succeeded in evoking four alternate lateral flexion movements of the head and trunk. With the head more or less fixed with cotton alongside, the movements were sufficiently powerful to move the body region. Decided backward and forward, choreic-like,

movements of the right and left forelimbs were observed.

- 9:01. Seen from the back, five alternate lateral flexion movements of the head and trunk (three to the left, two to the right).
C.R.L. in salt solution 14 mm. Two alternate lateral flexion movements of the head and trunk were evoked by touching the snout with the bristle. Abduction and adduction of the hindlimbs noted, but they were feeble.
- 9:10. A single touch of the bristle on the left side of the snout of the fetus evoked a right-left-right lateral flexion of the head and trunk movement.
- 9:11. Cut out into Bouin's Solution.

Fetus 4

Age at Beginning of Observation: 390 hours 26 minutes.

Time under Observation: 32 minutes.

C-R Length in Ringer's Solution: 14 mm.

- 9:43. Shelled out Fetus 4 from uterus and amnion.
P.M.
Observed two complete left-right-left alternate lateral flexion movements of the head and trunk in response to tactile stimulation of the snout of the fetus, using probe and bristle, and associated with this movement there was movement also forelimb forward and

backward movement.

- 9:53. Have succeeded in eliciting several definite lateral flexion movements of the head, away from the side touched, using the bristle and stimulating both right and left sides of the snout. Viewed from the back, the bend was at the level of the front limbs. Spontaneous lateral flexion movements of the head observed. They were weak. Contraction was first to the right, then to the left side, with feeble forward and backward movement of the forelimbs. Lateral flexion of the trunk does occur and is seen best from the back. Fetus is on its head! This fetus does not exhibit as much movement as Fetus 2. Almost, though!
- 10:07. A few weak lateral flexion of the head movements away from the side touched, stimulated snout both right and left sides, used the bristle. Temperature of the bath 37.5° C. C.R.L. 14 mm.
- 10:15. Stimulated snout with human hair, and the response was lateral flexion of the head and trunk, with feeble yet decided forward and backward movements of the forelimbs. No hindlimb movement observed. Trunk contracts quite far caudad. Cut out. Into Formalin.

RAT 62

Date of Insemination: Feb. 5, 1926, 4:48 P.M.

Date of Experiment: Feb. 21, 1926, 6:48 P.M.

Age at Beginning of Operation: 386 hours.

Fetus 3

Age at Beginning of Observation: 387 hours 24 minutes.

Time under Observation: 46 minutes.

C-R Length in Ringer's Solution: 14.5 mm.

8:12. Fetus 3 shelled out of the uterus and amnion.
P.M.

When the right side of the snout was touched the response was lateral flexion of the head to the left with forelimb abduction.

8:15. Touched left side of snout with bristle. Response was lateral flexion of the head to the right; weak and feeble. Again touched bristle to left side of snout; response was left-right lateral trunk flexion, strong movement. Touched bristle to side of back, but there was no response. Touched the bristle to the left side of the snout, and the response was lateral flexion of the trunk to the right side. Touched bristle to right side of snout, but there was no response; repeated the tactile stimulation, and on the fourth touch response was a feeble lateral flexion of the head to the left. There was no forelimb movement.

- 8:20. Stimulated right side of snout with the probe; the response was lateral flexion of the trunk to the left and head flexion with backward and forward movements of the right forelimb. The fetus is lying on the left side. Bristle touched to right side of the snout evoked a lateral flexion of the head to the left, but no forelimb movements. Bristle stroked over sides, shoulder and back (right side) did not evoke any response.
- Touched bristle to right side of snout; response was lateral flexion of the head only. Mother rat noisy.
- 8:24. Bristle to left side of snout evoked a lateral flexion of head to right. No forelimb movements.
- 8:25. By stimulating left side of snout with probe succeeded in obtaining a lateral flexion of the head to the right with weak backward movement of the left forelimb. Again the same stimulation, and the response was of the same nature except that there was no forelimb movement. Mother rat noisy.
- 8:30. Feeble spontaneous movements; lateral flexion of the trunk and choreic movement of the left forelimb. Bristle to the left side of the

snout evoked a lateral flexion of the trunk and head to the right with backward movement of left forelimb, then lateral flexion to left of trunk and rump, with abduction of the left hindlimb. Touching the left side of snout with bristle brought on lateral flexion of head and trunk to right; after a pause left forelimb backward movement.

Touching the back with bristle (left side) evoked a feeble backward movement of the left forelimb.

- 8:37. The response to stimulation of right and left sides of snout is away-from lateral flexion of head or trunk and rump with forelimb abduction and backward, or backward and forward, movement, and feeble movements of forelimb when side or back is stroked.
- 8:40. Feeble spontaneous abduction movements of the left hindlimb noted.
- 8:50. C.R.L. 14.5 mm.
- 8:56. Touched probe to left side of snout; response was lateral flexion of head to left.
- 8:58. Ligated umbilical cord. No movements. Cut out. Into Bouin's.

Fetus 5

Age at Beginning of Observation: 388 hours 26 minutes.

Time under Observation: 1 hour 8 minutes.

C-R Length in Ringer's Solution: 14.5 mm.

9:14. Fetuses 5 and 6 shelled out.
P.M.

9:16. Spontaneous alternate lateral flexion of trunk and rump with backward and forward movements of forelimbs noted in both fetuses.

9:20. Right side of snout touched with bristle; response was lateral flexion of head and trunk with vigor; backward and forward movement of both forelimbs, alternately. Spontaneous movements observed. Bristle touched to right side of snout; response was lateral flexion of head, trunk and rump to the left and continuing on other side; therefore, alternate lateral flexion of the head, trunk and rump, with backward and forward movement of the forelimbs and weak hindlimb abduction. Bristle touched to right side, over shoulder, evoked as a response lateral flexion of trunk, vigorous, of right side, with backward and forward movement of the forelimb. Again same response, which continued into alternate lateral flexion of head, trunk and rump.

9:31. Fetus 5 is spontaneously active, noted alternate lateral flexion of head, trunk and rump, with backward and forward movements of the

forelimbs with abduction, and abduction of the hindlimbs.

- 9:36. Movements seen in Fetus 5, spontaneous and in response to stimulation with the bristle, are: lateral flexion of head, trunk and rump; alternate lateral flexion of trunk; forward and backward movements with abduction of forelimb; hindlimb abduction with passive adduction; choreic paw movements which are feeble backward and forward movements of forelimb; the forelimbs alternate with each other, but follow the lateral flexion movements.

Both fetuses are sensitive to bristle on region of the shoulder, and touching over the shoulder often evoked forward and backward movement of the forelimb.

- 9:47. Fetus 5 has displayed many spontaneous movements, consisting of alternate lateral flexion of the trunk and rump and head, with backward and forward movements of the forelimbs and hindlimb abduction following lateral flexion of rump.

- 9:52. C.R.L. 14.5 mm. Spontaneous alternate lateral flexions of head, trunk and rump with backward and forward movements of the forelimbs and

- hindlimb abduction noted.
- 9:55. Spontaneous alternate lateral flexions of trunk and rump noted.
- 10:02. Many right-left-right or left-right-left alternate lateral flexions of the head, trunk and rump with backward and forward movements of the forelimbs and what flexion and extension there is possible of the forearm; but in the hindlimb abduction only, which follows along with the lateral flexion of the rump. Fetus is sensitive to bristle on side and rump, but the response is lateral flexion of trunk of same side, occasionally vigorous, with forward and backward, or backward and forward, movement of the forelimb. At times it appears as if head extension occurs in Fetus 5 spontaneously, but this I believe is only a quick lateral flexion of the head, followed by a quick lateral flexion of the trunk which makes it appear like head extension, and head extension does not occur when the fetus is on its back.
- 10:12. While ligating umbilical cord of Fetus 6 I accidentally made a stab wound in Fetus 5, in the right side over the liver, lateral to the spinal cord. Vigorous movements followed in

- Fetus 5, consisting of alternate lateral flexion of the trunk with rump following along, and backward and forward movements of the forelimbs. There was hemorrhage.
- 10:16. Touched bristle to left side of snout and response was lateral flexion of head and trunk to right with backward and forward movement with abduction of the left forelimb.
- 10:17. Spontaneous alternate lateral flexion of the trunk and rump and head with backward and forward movement of the forelimb and hindlimb abduction.
- 10:22. Ligated umbilical cord. Movements followed. Cut off right hind foot in tying knot. Alternate lateral flexion of trunk and rump followed with forward and backward movement of the forelimb. Cut out. Into Bouin's. It is certainly a wounded fetus.

Fetus 6

Age at Beginning of Observation: 388 hours 26 minutes.

Time under Observation: 1 hour 1 minute.

C-R Length in Ringer's Solution: 14.5 mm.

9:14. Fetuses 5 and 6 shelled out.
P.M.

9:16. Spontaneous alternate lateral flexion of

trunk and rump with backward and forward movements of forelimbs noted in both fetuses.

9:30. Fetus 6 is not nearly as active, nor does he perform as vigorous movements as does fetus 5. Movements are away-from lateral flexion of head, trunk and rump, with backward and forward movement of the forelimbs and abduction and adduction of the hindlimbs. He responds feebly with lateral flexion of head and backward movement of the forelimb when touched with bristle on side.

9:36. Movements seen in fetus 5, spontaneous and in response to stimulation with the bristle, are: lateral flexion of head, trunk and rump; alternate lateral flexion of trunk; backward and forward movements with abduction of forelimb; hindlimb abduction with passive adduction; choreic paw movements which are feeble forward movements of forelimb; the forelimbs alternate with each other, and follow the lateral flexion movements. Fetus 6 displays the same movements, but they are not so vigorous or so much repeated. Both fetuses are sensitive to bristle on region of the shoulder, and touching over the shoulder often evoked backward and forward movement of the forelimb.

- 9:47. Fetus 6 also is spontaneously active with the same movements, consisting of alternate lateral flexion of the trunk and rump and head, with backward and forward movement of the forelimbs and hindlimb abduction following lateral flexion of the rump. He does not display so many or such vigorous movements as Fetus 5. Response to stimulation of the snout with the bristle is away-from lateral flexion of the head and trunk, or head alone, or trunk and rump with backward and forward movement of the forelimb; or it may arouse alternate lateral flexion of head and trunk with forelimb and hindlimb movements.
- 9:52. C.R.L. 14.5 mm.
- 9:55. Spontaneous alternate lateral flexion of the trunk and rump noted.
- 10:02. Many right-left-right or left-right-left alternate lateral flexions of head, trunk and rump with forelimb backward and forward movements and what flexion and extension there is possible of the forearm; but in the hindlimb abduction and following along with the lateral flexion of the rump. The same holds true for Fetus 6, though this fetus is smaller.
- 10:12. Ligated umbilical cord of Fetus.6; there were no movements.

10:15. Fetus 6 into Formalin.

Fetus 7

Age at Beginning of Observation: 389 hours 40 minutes.

Time under Observation: 29 minutes.

C-R Length in Ringer's Solution: 14.5 mm.

10:28. Fetuses 7 and 8 shelled out. Noted in both P.M. spontaneous movements in amnion while shelling them out. The movements consisted of alternate lateral flexion of trunk and rump with forward and backward movement of the forelimb.

10:33. Many spontaneous movements seen, and these fetuses are just like fetus 5. Temperature of the bath 37.5° C. and has been so.

10:37. Stimulating the snout with bristle evoked away-from lateral flexion of trunk and head, or trunk or head alone. When the trunk flexion occurs the rump follows along, and the hindlimb abducts with it.

10:39. These fetuses are very sensitive to touch of bristle on snout and respond with surprising quickness. The mother rat is calm and has been so for a long time; no ether has been administered for some time. The fetuses are sensitive over shoulder and sides and rump, but not over the belly. The movements exhibited are: lateral flexion of the head,

trunk and rump with backward and forward movement of the forelimb and what flexion and extension of forearm there is possible. Hind-limb abduction and adduction occur in sequence with the rump lateral flexion. The forelimbs are very adept and paddle backward and forward with abduction and in some kind of order with the head and trunk lateral flexion. Alternate lateral flexion of head and trunk occurs, and this is a common spontaneous movements. No head extension or rump ventral flexion was noted.

10:48. C.R.L. 14.5 mm.

10:57. Ligated umbilical cord of Fetus 7. No movements occurred. Cut out. Into Bouin's Solution.

Fetus 9

Age at Beginning of Observation: 390 hours 17 minutes.

Time under Observation: 22 minutes.

C-R Length in Ringer's Solution: 14 mm.

11:05. Probe to left side of snout had as its response P.M. lateral flexion of the head to the right with backward and forward movement of the left forelimb. Again same response. Again touched probe to left side of snout, but response was weak same-side lateral flexion of the head.

- 11:07. Quite sensitive to bristle on sides; responses are forelimb backward movement with abduction and adduction of hindlimb, and these movements are quick. Once it evoked a same-side lateral flexion of trunk with backward movement of left forelimb and abduction of left hindlimb.
- 11:12. Bristle stroked over right shoulder evoked as a response lateral flexion of the trunk, quick, with right forelimb movement consisting of a straightening along the whole limb and backward movement (seen from the side). Bristle touched to right side of snout evoked left lateral flexion of head with forward and backward movement of forelimbs.
- 11:14. Spontaneous forward and backward movements of right forelimb. Touching right forelimb or paw with probe evoked twitches of the forelimb.
- 11:17. C.R.L. 14 mm.
- 11:19. Bristle stroked over right side and responses immediate and quick, were lateral flexion of trunk to the right, vigorous, followed by left lateral flexion of trunk, associated with movement of right forelimb backward, then forward and backward, and also hindlimb abduction.

Again, only one same-side lateral flexion of trunk involving the rump as well. No response to stroke of bristle.

11:24. Movements observed: unilateral head, trunk and rump flexion; forelimb forward and backward movement with abduction, and abduction and adduction of hindlimb; alternate lateral flexion of trunk, head and rump.

11:27. Ligated umbilical cord; no movements observed. Into Bouin's Solution. No more fetuses. Rat calm and has been. No ether administered for a long time, so that the last four fetuses were examined while the mother had no ether. But the last fetus suffered some from cutting of the vitelline veins of the chorion. Killed the mother rat. Temperature of the bath 37.5° C. and was constant throughout the experiment.

RAT 58

Date of Insemination: Jan. 20, 1926, 2:30 P.M.

Date of Experiment: Feb. 5, 1926, 8:36 P.M.

Age at Beginning of Operation: 390 hours 6 minutes.

Fetus 3

Age at Beginning of Observation: 391 hours 10 minutes.

Time under Observation: 58 minutes in amnion;

27 minutes shelled out.

C-R Length in Ringer's Solution: 14.5 mm.

9:10. Fetus 3 shelled out of the uterus.
P.M.

9:40. Noted spontaneous alternate right, left,
right lateral flexions of the trunk and
also of the rump.

10:04. Observed the "peculiar" alternate lateral
movements of the tail. This fetus is still
intact in the amnion. Observed more vigor-
ous lateral flexion movements of the rump
with abduction of the hindlimb.

10:08. Shelled out the fetus from the amnion. This
fetus responds more vigorously than fetus 1
and fetus 4; spontaneous movements. Touched
with bristle either right or left side of
snout, and the responses were lateral flexion
of the head and trunk away from the side touched
with movement first of the forelimb of the side
touched followed by movement of the forelimb
of the opposite side and lateral flexion of the
trunk of this side.

10:14. Noted spontaneous alternate lateral flexion of
the trunk with abduction and backward movement
of the forelimb which is at times very quick
and appears like "reaching" or extension and
flexion. Noted that occasionally spontaneous
movements of the forelimb only occur and the

movement consists of flexion and extension of the forearm. The forelimbs are quite adept in their movements.

10:17. Much spontaneous activity consisting of forelimb movements and alternate lateral flexion of the trunk.

10:20. When the sides, back and rump are stroked with bristle it usually calls forth vigorous lateral flexion of the trunk with forelimb movement of abduction and adduction, forward and backward movement, and flexion and extension of forearm, the forelimbs alternating with each other. Have observed hindlimb abduction during lateral flexion of the rump and trunk.

10:25. The movements so far observed and summarized are as follows: alternate lateral flexion of the head, trunk and rump; abduction and forward and backward movements of the forelimb; abduction of the hindlimb followed by adduction; probable flexion and extension of the forearm; unilateral flexion of the head, trunk and rump. The forelimb and trunk movements are the most pronounced and best-executed movements, then the head and rump follow. The hindlimb movements are associated with the rump movements and are last in order of develop-

ment.

10:30. Noted spontaneous movements, consisting of alternate lateral flexions of the trunk. They are slow and progress from the shoulder down the trunk to the rump and may repeat with one, two or even three contractions on the one side; following this the contraction occurs on the opposite side. The forelimb "reaches" or extends backward during the height of the lateral trunk flexion, after which it pulls back unsteadily.

C.R.L. 14.5 mm. in salt solution.

10:35. Ligated the umbilical cord and vessels and very soon "twitch-like" movements of the forelimbs and trunk occurred.

Into Bouin's Solution.

Fetus 4

Age at Beginning of Observation: 390 hours 47 minutes.

Time under Observation: 40 minutes.

C-R Length in Ringer's Solution: 14 mm. plus.

9:11. Shelled out from the uterus.
P.M.

9:17. Shelled out from the amnion. Touched the right side of the snout of the fetus and the response was feeble lateral flexion of the head.

C.R.L. 14 mm.

- 9:20. Noted a feeble spontaneous lateral flexion movement of the head to the left and forward and backward movement of the forelimbs.
- 9:21. Touched the left side of the snout of the fetus with the bristle and the response was lateral flexion of the trunk to the right side and back to normal position. There occurred some forward and backward forelimb movement of the left forelimb.
- 9:25. Have touched the left and right sides of the snout of the fetus and the responses are lateral flexion of the trunk and head away from the side touched, with backward and forward movement of the forelimbs.
- 9:27. Stroked the bristle over the right shoulder region and the response was backward movement of the right forelimb (viewing the fetus as it is lying on its left side) and weak lateral flexion of the head to the right.
- 9:28. The bristle touched to the right side of the snout of the fetus and the response was a single lateral flexion of the head and trunk to the left, with decided abduction of the right forelimb.
- 9:34. Have tried "bristle to the snout" right and left sides, and the response is lateral flex-

ion of the trunk and head. The former are more vigorous than the latter movements, and they are away from the side touched with abduction first of the forelimb on the side touched followed by abduction of the forelimb of the other side.

- 9:38. Again the same responses; also bristle touched to the rump aroused a lateral flexion of the trunk of the same side touched. In this instance it was the right side. The movement of the forelimb is decidedly abduction to the side and due to the shape and position of the forelimb the movement is backward and of the limb as a whole.
- 9:48. Noted abduction of the hindlimbs.
- 9:57. Fetus 4 into Bouin's. C.R.L. 14.5 mm.
- 10:25. See Fetus 3. Same record.

Fetus 5

Age at Beginning of Observation: 392 hours 15 minutes.

Time under Observation: 18 minutes.

C-R Length in Ringer's Solution: 14.5 mm.

- 10:45. Fetus 5 shelled out of the uterus and amnion.
P.M.
Very active. Sensitive to bristle touched to the snout, which aroused the usual away-from lateral flexion of the head or trunk, or both, and well-executed movement of the forelimbs

- backward with abduction. Sensitive to the touch of the bristle on sides, shoulder and back, but more so in the shoulder region.
- 10:53. Fetus 5 reacts the same way that the other fetuses did. C.R.L. 14.5 mm.
- 10:55. Observed spontaneous alternate lateral flexion of the trunk; it was a vigorous movement. The fetus is very sensitive to the touch of the bristle on the snout. Hindlimb abduction observed. Very well-executed forelimb movement involving extension and flexion of forearm and abduction.
- 11:03. Ligated the umbilical cord and vessels of Fetus 5 and twitch-like movements followed. Into Bouin's. C.R.L. 14.5 mm. Temperature 36.5° C.
- 11:07. No more fetuses.

PROTOCOLSDorso-ventral extension-flexion stageRAT 50

Date of Insemination: Jan. 8, 1926, 1:58 P.M.

Date of Experiment: Jan. 24, 1926, 7:58 P.M.

Age at Beginning of Operation: 390 hours.

Fetus 5

Age at Beginning of Observation: 393 hours 2 minutes.

Time under Observation: 29 minutes.

C-R Length in Ringer's Solution: 15 mm.

- 11:00. Fetus 5 shelled out--touched the left side
P.M. of the snout of the fetus with the probe and
its response was lateral flexion of the head
to the right with backward movement of the
left front limb.
- 11:01. Observed spontaneous movements which were
alternate lateral flexion of the head, trunk
and rump to the right, left, right, left with
backward and forward movement of the left
front limb.
- 11:03. Observed vigorous spontaneous alternate lat-
eral flexion movements to the right, left,
right, left, right, left, and two very quick
head extension movements.

- 11:07. Observed spontaneous movements. Stroked the bristle over the right side of the snout of the fetus and the response was lateral flexion of the right side with forward and backward right forelimb movement. 60
- 11:10. Feeble hindlimb abduction, which was associated with lateral flexion of the rump, occurred.
- 11:12. Observed six head extension movements. I touched the snout with the tissue forceps. These head extension movements were grouped as follows: first group, two movements; second group, three movements; third group, one movement; and the last head extension was followed by lateral flexion of the head to the left.
- 11:20. Stroking the bristle over the side region of the shoulder, three times, evoked delicate but quick forward movement of the forelimb and the movement was of only the forearm. It was flexion and extension of the forearm. There was no "reaching" of the forelimb.
- 11:22. Observed spontaneous movements which consisted of five alternate lateral flexion movements of the trunk, head and rump, and were associated with forward and backward movement of the forelimb. C.R.L. in salt solution 15 mm.
- 11:27. Clamped the umbilical vessels with the tissue

forceps and the movements evoked were nine alternate lateral flexion movements of the head, trunk and rump associated with forward and backward movement of the forelimbs. There occurred one very quick head extension movement.

11:29. Clamped the umbilical vessels with tissue forceps, and six alternate lateral flexion movements of the head, trunk and rump associated with forward and backward movement of the forelimbs occurred. There was no head extension. Temperature 38.5° C. Cut out Fetus 5. Into Bouin's Solution. There were no more fetuses.

RAT 69

Date of Insemination: March 13, 1926, 10:29 A.M.
 Date of Experiment: March 29, 1926, 7:29 P.M.
 Age at Beginning of Operation: 393 hours

Fetus 1

Age at Beginning of Observation: 393 hours 38 minutes.
 Time under Observation: 41 minutes.
 C-R Length in Ringer's Solution: 15.5 mm. plus.

Simple Movements Observed

Lateral flexion of the head, trunk and rump.
 Alternate lateral flexion of the trunk, head and rump.

Backward and forward movement of the forelimbs with
abduction.

Hindlimb abduction

Flexion and extension of the forearm.

Head extension.

Rump ventral flexion.

Mouth opening movements.

Tongue movement.

8:07. There are four fetuses in the left horn and
P.M. three in the right horn.

8:08. Fetus 1 shelled out of the amnion. Movements
noted: alternate lateral flexion of the trunk
and head; forelimb forward and backward move-
ments with abduction; rump ventral flexion;
flexion and extension of forearm; spontaneous
movements.

8:12. Bristle to left side of snout with a light
touch evoked as a response: both forelimbs
backward movement with abduction; lateral
flexion of head, trunk and rump to the right
followed by hindlimb abduction and rump ventral
flexion; a brief pause ensued, then head ex-
tension occurred.

8:13. Bristle stroked over the left shoulder brought
on lateral flexion of trunk to left, with fore-
limb abduction and hindlimb abduction; followed

by alternate lateral flexion of trunk and head.

- 8:16. Bristle touched to left side of belly; response was lateral flexion of the trunk and rump with forward and backward movement of forelimb and hindlimb abduction.
- 8:17. Bristle on right side of snout evoked alternate lateral flexion of trunk and head with forelimb forward and backward movement, then head extension and quick mouth opening. Feeble tongue movements were noted. Fetus was very sensitive on snout, shoulder, flanks and belly. Again noted tongue and mouth movements. The flanks are very sensitive even using extremely light touch.
- 8:20. Noted quick head extension followed by rump ventral flexion with forelimb movements. Forelimb flexes and extends at forearm. Movements so far have consisted of: Head: lateral flexion, alternate lateral flexion, extension; Mouth and tongue: movements were definite; Trunk: lateral flexion and alternate lateral flexion; Rump: lateral flexion and ventral flexion; Hindlimb: abduction and adduction. Fetus is sensitive over snout, shoulder, back, flanks and belly.

- to single touch of bristle.
- 8:26. Noted vigorous head extension with mouth and tongue movements when the left side of the rump was touched with the caliper point.
- 8:28. C.R.L. 15.5 mm. plus. Have noted four quick head extensions with mouth opening and tongue movements. Bristle to back of neck caused three times quick head extension response which was associated with mouth, tongue and backward forelimb movements. Temperature of the bath 36.5° C.
- 8:42. Independent spontaneous forearm flexion and extension has been observed in both Fetus 1 and Fetus 2.
- 8:45. Spontaneous mouth opening and tongue movements with alternate lateral flexion of trunk, and head extension; flexion and extension of the forearm; forward and backward movements of the forelimbs, with hindlimb abduction during the lateral flexion of the rump were observed.
- 8:48. Fetus 1 in Bouin's. Movements followed ligation of the umbilical cord.

Fetus 7

Age at Beginning of Observation: 396 hours 3 minutes.

Time under Observation: 44 minutes.

C-R Length in Ringer's Solution: 15.5 mm.

Simple Movements Observed

Lateral flexion of the head, trunk and rump.

Alternate lateral flexion of the trunk, head and rump.

Backward and forward movement of the forelimbs, with
abduction.

Hindlimb abduction.

Flexion and extension of the forearm.

Head extension.

Rump ventral flexion.

Mouth opening movements.

Tongue movement.

Maintained lateral flexion of the trunk - questionable.

10:32. Fetus 7 shelled out of uterus and amnion.
P.M.

Temperature of the bath 37° C. Spontaneous alternate lateral flexion of trunk and head with forelimb movements consisting of forward and backward, flexion and extension of forearm, with abduction. Hindlimb abduction associated with flexion of rump noted.

10:38. Very responsive to bristle to snout, right and left sides, shoulder, back and flank, also belly. The usual responses evoked as mentioned in the other fetuses. Head extension was noted as response to stimulation of snout by bristle, also spontaneous, and associated with tongue and mouth movements. But rump

ventral flexion occurs during the series of alternate lateral flexions of trunk and may precede or follow head extension or occur alone. The forelimb movements are all well-executed.

10:44. It was noted that touching the bristle to the snout does not always evoke head extension, but only occasionally. Often the response is lateral flexion of trunk or head.

10:45. Fetus 7 is very active and easily aroused by bristle to snout, with the away-from movement; and movement toward the side touched when stimulated over shoulder, flanks, back (lateral) and belly. The maintained lateral flexion in any of these fetuses is questionable since it does not last long enough. It is probably a vigorous lateral flexion of the trunk, therefore, with slight indication of the posture movement. In other words, it marks the very beginning of the posture movement. Further tongue movement may apparently occur without mouth opening, as the mouth is always slightly open, but the lower jaw did move perceptibly in all of the fetuses.

10:53. Noted flexion and extension of right fore-arm, twice in succession. This was followed

by lateral flexion of the trunk to the right and forward and backward movement of the forelimb with flexion and extension; and lateral flexion of the rump with hindlimb abduction and adduction.

- 10:57. C.R.L. 15.5 mm. Noted ventral rump flexion, a spontaneous movement. Noted head extension, a quick movement. Temperature of the bath 37° C.
- 11:06. For the last eight minutes I have studied and watched the almost continuous spontaneous movements of Fetus 7. These consisted of the movements already mentioned. Once there occurred during a series of alternate lateral flexions of the trunk a vigorous head extension with mouth opening and tongue protrusion. Hindlimb and forelimb movement may be in series, or sequence, as was observed, but the hindlimb movements are only crude abduction, while the forelimb movements are well-executed.
- 11:12. Fetus 7 is still very active spontaneously. Noted again maintained lateral flexion of the trunk.
- 11:14. Noted quick spontaneous head extension.
- 11:16. Ligated umbilical cord. Movements followed, consisting of alternate lateral flexion of

trunk and a weak head extension movement followed, associated with quick backward forelimb movement. Temperature of the bath 37° C.

11:17. No more fetuses. Killed the mother rat.

There was no head rotation. As stated above, maintained lateral flexion of the trunk was of the very early type.

RAT 61

Date of Insemination: Jan. 26, 1926, 4:54 P.M.

Date of Experiment: Feb. 12, 1926, 4:54 A.M.

Age at Beginning of Operation: 396 hours.

Fetus 2

Age at Beginning of Observation: 396 hours 30 minutes.

Time under Observation: 40 minutes.

C-R Length in Ringer's Solution: 15 mm.

5:18. Shelled out of the uterus.
A.M.

5:28. Shelled out of the amnion. Noted spontaneous hindlimb abduction movements which are of common occurrence and they follow in sequence, of some order, the forward and backward movements of the forelimbs. Noted head extension which was quick, two times it occurred, also lateral flexion of the trunk. Touched the snout,

right side, with the bristle and the response was a lateral flexion of the trunk. Noted spontaneous alternate lateral flexion of the trunk with the forelimbs alternating with each other in forward and backward movement and reaching. Hindlimb movements of abduction and adduction observed.

- 5:42. Bristle touched to either the right or left side of the snout evokes for the first two or three times touched an away-from lateral flexion of the head with forward and backward movement of the forelimbs, the left and right forelimbs alternating with each other. Further stimulation evoked an away-from lateral flexion of the trunk with the forelimb forward and backward movements.
- 5:48. The two fetuses, Fetus 1 and Fetus 2, have been very active. Both are quite alike in movements displayed. Hindlimb abduction and adduction is a rather definite movement.
- 6:00. Noted spontaneous alternate lateral flexion of the head, trunk and rump with well-executed forelimb forward and backward movement, also flexion and extension of the forearm and hindlimb abduction and adduction.
- 6:06. Ligated the umbilical cord and vessels. Move-

ments followed, which were alternate lateral flexion of the trunk, forward and backward movement of the forelimb, hindlimb abduction and adduction and one head extension. The movements gradually faded out and became twitch-like.

- 6:07. The fetus responded feebly to bristle touched to the left side of the snout by a lateral flexion of the head to the right.
- 6:08. No response to tactile stimulation. The heart is beating.
- 6:09. Into Formalin. Temperature 37.5° C. C.R.L. 15 mm. Movements observed in order of most common occurrence were: alternate lateral flexion of the trunk and head and rump; forward and backward movement of the forelimb; flexion and extension of the forearm; hindlimb abduction and adduction; head extension; no rump ventral flexion observed; no tongue or mouth movements observed; forelimb movements well-executed, alternating with each other.

Fetus 3

Age at Beginning of Observation: 397 hours 30 minutes.

Time under Observation: 22 minutes.

C-R Length in Ringer's Solution: 15 mm.

- 5:18. Shelled out of the uterus.
A.M.
- 6:16. Shelled out of the amnion. The fetus is very active. Touched the right side of the snout with the bristle and the response was lateral flexion of the head to the left with forward and backward movement of the forelimbs. This was followed by lateral flexion of the trunk on the same side touched (right).
- 6:20. Touched the right side of the belly region with the bristle and the response was lateral flexion of the trunk to the right side. It was a slow movement followed by two head extension movements. Hindlimb movements were observed. Alternate lateral flexion of the trunk was very vigorous. Many alternate lateral flexion movements of the trunk. Probe touched to the right side of the snout evoked head extension. Sides and back touched with the bristle evoked lateral flexion of the trunk of the same side touched, with forelimb and hindlimb movement.
- 6:29. Touching the bristle to the snout invariably evoked lateral flexion of the head to the opposite side, with forward, then backward, movement of the forelimbs and flexion and

extension of the forearm.

Temperature of the bath 37.5° C.

- 6:31. Observed spontaneous alternate lateral flexion movements of the trunk, very vigorous and with head extension, also alternate lateral flexion of the head and trunk with forward and backward movement of the forelimbs and abduction and adduction of the hindlimbs.
- 6:34. Mother rat very restless. She has been very quiet until now and taken very little ether.
- 6:37. Fetus 3, C.R.L. 15 mm.
- 6:38. Ligated the umbilical cord of Fetus 3. Vigorous alternate lateral flexion movements of the trunk followed within three or four seconds, alternate forward and backward forelimb movements, hindlimb abduction and adduction, and one head extension movement noted.
- 6:40. Fetus 3 into Bouin's.

RAT 56

Date of Insemination: Jan. 15, 1926, 4:31 P.M.

Date of Experiment: Feb. 1, 1926, 7:05 A.M.

Age at Beginning of Operation: 398 hours 34 minutes.

Fetus 2

Age at Beginning of Observation: 399 hours 41 minutes.

Time under Observation: 1 hour 50 minutes.

C-R Length in Ringer's Solution: 15.5 mm. minus.

7:43. Shelled out of the uterus.
A.M.

8:12. Fetus 2 shelled out of the amnion. Move-
ments noted. Mouth opening. Touched the
right side of the snout with the probe and
the response was lateral flexion of the head
to the left and forward and backward movement
of the forelimbs.

Probe touched to the left side of the snout,
response was lateral flexion of the head to
the right with forward and backward forelimb
movements.

8:17. The fetus failed to respond to the bristle
touched to the right and left sides of the
snout. Touched the left side of the snout
with the bristle and the response was feeble
extension of the forearm of the left limb
only.

8:18. Touched the right side of the snout of the
fetus with the probe and the response was a
vigorous lateral flexion of the head, trunk
and rump of the left side; with backward move-
ment of the right forelimb and forward move-
ment of the left, followed by reverse movement
of the forelimbs.

8:20. Touched the left side of the snout with the

bristle and the response was lateral flexion of the head, trunk and rump of the right side with forward and backward movement of the forelimbs and then lateral flexion of the head, trunk and rump of the left side.

8:22. Touched to left side (shoulder and thorax) with bristle and the response was lateral flexion of the left side of the trunk which was followed by vigorous ventral flexion of the rump.

8:23. Prodding the snout of the fetus with the flat side of the probe evoked the usual lateral flexion movements of the head, trunk and rump and also ventral flexion occurred at three different times.

8:26. Spontaneous movements noted which were alternate lateral flexion of the trunk and backward movement of the left forelimb. Vigorous quick head extension followed by rump ventral flexion and forward and backward forelimb movement. The fetus is propped up on its back by cotton!

8:29. Noted, three in rapid succession, head extension movements with backward extension of the left and right forelimbs. This was a spontaneous movement.

8:36. Prodding the body region with the bristle lightly shows by the responses that the fetus

is sensitive to tactile stimulation over the shoulder, back, sides and rump, and probably sensitive over the dorsal surface of the forearms.

- 8:38. Noted a spontaneous movement which consisted of head extension followed by lateral flexion of the trunk and forward and backward movement of the forelimbs. The hindlimbs in both fetuses exhibited abduction and adduction movements.
- 8:40. Noted spontaneous movements of quick head extension followed by forward and backward movement of the forelimbs more or less together, then with a jerk ventral flexion of the rump occurred, slower but more powerful than the head extension.
- Fetus 2 C.R.L. 15 mm.
- 8:42. Touched the left side of the snout with the probe and the response was lateral flexion of the head with rotation to some extent or degree, mouth opening and tongue movements, also forward and backward movements of the forelimbs.
- 8:44. Touched the left side of the snout of the fetus with the probe and the response was the usual lateral flexion of the head to the right with rotation and then many alternate

lateral flexion movements of the trunk and rump, emphasized by two ventral flexion movements of the rump.

- 8:46. Noted spontaneous movements which consisted primarily of alternate lateral flexion of the trunk and forward and backward movement of the forelimbs. The lateral flexion of the trunk movements are slow and maintained and associated with maintained extension of the forelimb of the same side.
- 8:56. Touched the snout with the bristle and observed slow tongue protrusion movement along with other movements of the trunk and limbs.
- 9:00. Noted spontaneous head extension with tongue movement; again tongue movements; they are very feeble and slow. The mouth did not open.
- 9:11. Noted spontaneous movements. Temperature 37.5° C.
- 9:22. Have observed the spontaneous and tactile responses of the four fetuses now exposed. They consist of movements of alternate lateral flexion of the head, trunk and rump; forward and backward movement of the forelimbs; flexion and extension of the forearm; abduction and adduction of the hindlimbs; head extension and rump flexion, but rump ventral flexion was

more vigorous than head extension. Lateral flexion of the trunk was vigorous and maintained for two or even three seconds. Have observed tongue movements. They were slow and cannot decide whether they were protrusion or retraction.

The fetuses are sensitive to the bristle or probe touched to the snout, back, sides, and rump, but sensitivity was doubtful on dorsum of the forearm.

The response to bristle touched to the side of the snout was lateral flexion of the head, trunk and rump of the opposite side with forward and backward movement of the forelimbs, alternating with each other and with the trunk contraction. Have verified this three times.

- 9:32. The fetuses are very active now--spontaneously--and respond vigorously to bristle touched to the snout and sides.
- 9:36. The mother rat has been very quiet now for a long time. No ether. Temperature 38° C.
- 9:40. Tongue movements every time the snout is touched with bristle noted to occur in fetuses 2 and 5.
- 9:42. The movements of alternate lateral flexion or lateral flexion are maintained briefly, 2

or 3 seconds, and were the most vigorous; next are the forelimb movements.

9:48. The movements observed in these fetuses are: alternate lateral flexion of the head, trunk and rump; at times lateral flexion of the head, trunk and rump occurs; head extension with rotation; rump ventral flexion; hindlimb abduction and adduction; forelimb forward and backward as a whole, with abduction; flexion and extension at the forearm.

Tongue movements in Fetuses 2 and 5, but not in Fetuses 3 and 4. Mouth opening. Maintained lateral flexion of the trunk with maintained extension of the forelimb of the same side.

9:51. C.R.L. of Fetus 2, 15 mm. plus.

10:02. Ligated umbilical cord and vessels. Observed the characteristic movements which usually follow ligation of the umbilical vessels. Into Bouin's Solution.

RAT 41

Date of Insemination: Nov. 27, 1925, 4:35 P.M.

Date of Experiment: Dec. 14, 1925, 10:10 A.M.

Age at Beginning of Operation: 401 hours 35 minutes.

Fetus 6

Age at Beginning of Observation: 405 hours 13 minutes.

Time under Observation: 1 hour 19 minutes.

C-R Length in Ringer's Solution: 15 mm.

- 1:48.
P.M. Fetus 6 shelled out from the uterus and amnion. Ligated the vitelline vessels, before the chorion was cut, with silk thread. Observed a lateral flexion of the head to the right and left sides.
- 1:49. Stimulated the snout, using the bone probe, and the response was lateral flexion of the head with forward and backward movement of the forelimbs, also flexion and extension of the forearm and mouth opening with protrusion of the tongue. Observed mouth and tongue movements again. Noted maintained lateral flexion of the trunk with reaching of the forelimb on the side opposite from that on which contraction occurred. C.R.L. 15 mm. in salt solution.
- 2:03. Have tried to make the fetus stick out the tongue, but failed. The response to touching the snout of the fetus is an away-from lateral flexion of the head, trunk and rump, also forelimb forward and backward movement and flexion and extension of the forearm with reaching-out movement, and abduction and adduction of the hindlimbs. There occurred

ventral flexion of the rump but doubtful flexion of the head. Extension of the head occurs often and the movement is quick, modified with rotation of the head.

- 2:20. No tongue movements can be evoked. The response is lateral flexion of the head, trunk and rump.
- 2:24. Fetus 6 is remarkably sensitive to the stroke of the bristle along the back and side. The immediate response is a vigorous lateral flexion of the whole trunk. The contraction occurred on the side stroked. This was followed immediately by forward extension of the forelimbs and backward movement of the forelimbs, also lateral flexion of the head. Maintained lateral flexion of the trunk and rump was a common spontaneous movement. It may last for three, four, even seven seconds, and every second or so it is periodically emphasized by additional efforts, contractions on the same side to hold the maintained lateral flexion of the trunk and rump. The rump does the emphasizing.
- 2:40. Again mouth opening (the mouth is always open, but opens wider when the tip of the caliper is held on the snout). During the response

mouth-opening, tongue-protrusion movement
was observed.

3:07. Fetus 6 into Bouin's Solution.

RAT 55

Date of Insemination: Jan. 14, 1926, 3:05 P.M.

Date of Experiment: Jan. 31, 1926, 11:20 A.M.

Age at Beginning of Operation: 404 hours 15 minutes.

Fetus 2

Age at Beginning of Observation: 405 hours 28 minutes.

Time under Observation: 1 hour 33 minutes.

C-R Length in Ringer's Solution: 15.5 mm. plus.

12:03. Shelled out of the uterus.
P.M.

12:33. Shelled out of the amnion. The fetus is
very active. Have observed many vigorous
movements. The snout is very sensitive to
the bristle or probe and so are the sides,
back and rump. Movements observed were:
lateral flexion of the head, trunk and rump;
alternate lateral flexion of the head, trunk
and rump; head extension; tongue protrusion
and mouth opening; rump ventral flexion;
maintained lateral flexion of the trunk,
right side; flexion and extension at the
forearm of the forelimbs; forward and back-

ward movement of the forelimb as a whole;
hindlimb abduction and adduction.

- 12:50. Clamping the umbilical vessels with the tissue forceps brings on movements of the trunk, head, rump and forelimbs.
- 12:54. Touched the mouth, inside, with the bristle and the movements evoked were alternate flexion of the trunk with forelimb movement. Tried this five times and each time the response was the same as noted above.
- 1:14. Movements observed in Fetuses 2, 3, and 4 are as follows: alternate and unilateral flexion of the head, trunk and rump; head extension with rotation of the head; head flexion when the rump flexes; rump ventral flexion; forward and backward movement of the forelimbs; flexion and extension of the forearm; hindlimb abduction and adduction; mouth opening and closure; tongue movements; rather maintained head extension with quite prolonged mouth opening and tongue protrusion movements.
- 1:34. Temperature of the bath 37° C. Movements observed in Fetuses 2, 3, 4, and 5. Head extension with mouth opening and tongue protrusion; rump ventral flexion with movement of the whole forelimb, thorax, and head on the abdomen! Al-

ternate lateral flexion of the head and trunk and rump which is associated with forelimb forward and backward movement with abduction, and all are associated with head extension. Flexion and extension of the forearm may occur independently as a feeble movement of spontaneous origin or at times when the bristle is stroked over the snout or sides. Slightly maintained head extension with mouth and tongue movements, also lateral flexion of the trunk. Hindlimb abduction and adduction with lateral flexion of the rump sometimes following in diagonal sequence with the forelimb movement. The dorsal surface of the forelimb seems to be sensitive to very light strokes with the bristle, especially in Fetus 4. Stroked over the sides, back and rump, the fetuses responded vigorously with lateral flexion of the trunk, head, and rump; the contraction was of the same side touched. Clamping the umbilical vessels with the tissue forceps within a few seconds caused movement to occur which was alternate lateral flexion of the trunk, rump and head, associated with forelimb movements and at times tongue and mouth movements. Tried this clamping of the umbilical vessels with the tissue

forceps on all of the fetuses except Fetus 1, and with the same results as recorded above.

- 1:50. C.R.L. Fetus 2, 16 mm. minus, or 15.5 mm. plus.
- 1:55. Ligated the umbilical vessels of Fetus 2 with silk thread. Within a few seconds movements of the forelimbs and trunk took place. Into Formalin.

RAT 52

- Date of Insemination: Jan. 11, 1926, 3:50 P.M.
- Date of Experiment: Jan. 28, 1926, 1:02 P.M.
- Age at Beginning of Operation: 405 hours 12 minutes.

Fetus 2

- Age at Beginning of Observation: 405 hours 55 minutes.
- Time under Observation: 1 hour 55 minutes.
- C-R Length in Ringer's Solution: 16 mm.
- 1:45. Shelled out of the uterus.
P.M.
- 1:53. Shelled out of the amnion. Noted feeble lateral flexion of the head in response to bristle touched to the left side of the snout.
- 1:55. Fetus 2. Noted four head extension movements of spontaneous origin. Observed head extension with mouth opening and tongue protrusion; alternate lateral flexion of the trunk and rump; head extension with mouth opening and tongue pro-

trusion; rump ventral flexion with backward movement of the forelimbs, more or less together; head extension.

- 2:00. Fetus 2 is more active, spontaneously, than Fetus 1. Both are easily roused by the bristle touched to the snout, or on sides and back, and give responses of head extension with rotation away from side touched, also alternate lateral flexions of the head, trunk and rump. Mouth opening with tongue movements observed.
- 2:07. Temperature of the bath 37° C. Fetus 2 is very active with spontaneous movements. Touched on the snout, left side, with bristle; the response movements were: vigorous lateral flexion of the trunk to the right; movement forward with extension laterally of the forelimb. The head rotated to the right and extended during the initial contraction of the trunk and the tongue was protruded. Bristle touched to the right side of the snout-- response was vigorous lateral flexion of the left side of the trunk and head and the right forelimb moved upward, slightly flexed at the elbow, then abducted laterally and the while extended it moved backward quickly.
- 2:23. Movements observed in Fetus 2: alternate

lateral flexion of the trunk and head; head extension with rotation; forelimb forward and backward, with abduction; flexion and extension of the forearm at the elbow; hindlimb abduction with passive adduction; rump ventral flexion; lateral flexion of the rump; alternate lateral flexion of the rump associated with alternate lateral flexion of the trunk; tongue movements of protrusion and retraction (passively). Mouth opening. Maintained lateral flexion of the trunk. Maintained forelimb extension.

2:30. Temperature 37° C.

2:43. The most vigorous movements are alternate lateral flexion of the trunk and rump ventral flexion. The latter movement, at times, is so powerful that it raises the whole head and forelimbs up and off the net in which the fetus is lying. Forelimb movement is vigorous, too, and is associated with trunk and head movements.

2:47. Spontaneous movements in Fetus 2.

2:55. The fetus is easily roused by the bristle and the human hair readily evoked responses.

3:19. The fetuses can be roused and respond to tactile stimulation using a single fine rat hair. It

is easier to elicit a response by stroking in the region of the shoulder and back than it is of the snout. But pulling or prodding in the mouth, using the rat hair, did evoke a vigorous lateral flexion of the trunk to the right with head extension, modified by rotation of the head.

3:25. This fetus has exhibited some very prominent maintained lateral flexions of the trunk. The movement was associated with vigorous lateral flexion of the rump as a whole and toward the same side on which the maintained lateral flexion of the trunk occurred. While the maintained lateral flexion of the trunk occurred, the rump at irregular intervals flexed laterally and occasionally ventrally; also occasionally there occurred quick and vigorous head extension which generally followed the rump ventral flexion, not always, but often, this was the case; associated with the maintained lateral flexion of the trunk was flexion of the forearm, followed by maintained extension of the forelimb as a whole, of the same side, then backward movement of this forelimb associated with rump ventral flexion occurred.

- 3:40. Fetus 2 is pale (dead). No response. C.R.L.
a little more than 16 mm. late measurement.
- 3:44. Into Bouin's Solution.

RAT 33

- Date of Insemination: Nov. 11, 1925, 3:50 P.M.
- Date of Experiment: Nov. 28, 1925, 2:22 P.M.
- Age at Beginning of Operation: 406 hours 22 minutes.

Fetus 1

- Age at Beginning of Observation: 406 hours 50 minutes.
- Time under Observation: 3 hours 10 minutes.
- C-R Length in Ringer's Solution: 16 mm.
- 2:46. Shelled out of the uterus.
P.M.
- 2:50. Shelled out of the amnion. Spontaneous move-
ments observed. Noted lateral flexion of the
trunk and head, head extension; mouth opening
when probe was held or touched to the snout.
Bristle stroked over the side aroused lateral
flexion of the trunk on the side touched, fol-
lowed by choreic forelimb flexion and extension
movement, also abduction and adduction of the
hindlimbs.
- 3:15. Very vigorous lateral flexion of the trunk or
maintained lateral flexion of the trunk empha-
sized by very quick rump ventral flexions.
Positive movement of the tongue and mouth open-

- ing when the probe was held on the snout.
- 3:17. Positive opening of the mouth with protrusion and retraction of the tongue when probe was held on the snout.
- 3:18. Mouth opening and tongue protrusion and vigorous head extension when the bone probe was held on the snout. The forelimbs involved in this response.
- 3:47. Spontaneous movements consisting of lateral flexion of the head and trunk with choreic forelimb movements; ventral flexion of the rump and extension of the head.
- Greatest amount of activity is in the trunk, rump and forelimbs with occasional head extension and lateral flexion of the head. Most of the time the head is fixed while the trunk and rump display lateral flexion movements. Have noted that when the rump ventral flexion takes place the liver region becomes pale. Forelimbs move at times without any other movement preceding or following and a stroke with the bristle over the dorsal surface of the forearm and paw evoked flexion and extension of the forearm. This indicates that this region is sensitive to touch.
- 3:58. Temperature of the salt solution 36° C.

Warmer solution added. Temperature 37° C. at 4:05 P.M. Noted spontaneous mouth opening. While this occurred tongue movements were observed. These tongue movements may be lateral and raising of the tongue, it is hard to tell. They may also be protrusion and retraction of the tongue.

Fetus 1, following four drops of ether to the mother rat on mask over the nose, noted two lateral maintained flexion movements of the trunk; each lasted about four seconds. Noted also very rapid head extension and rump extension, which was quick as a flash. Lateral flexions of the rump are at times very quick.

- 4:18. Fetus 1, C.R.L. 16 mm. He has been very active.
- 4:56. Fetus 1 active spontaneously and can be roused by tactile stimulation.
- 5:30. Fetus 1 still spontaneously active, even more than the others. There is a blotch of blood on the left side of the face and there are tiny blotches over the head and larger on the neck.
- 5:47. Fetus 1 still responds.
- 6:04. Fetus 1 cut out. Still alive when cut out. Into Formalin.

Fetus 1 was active throughout the experiment, which shows that the placental-maternal relations were intact and functioning for three hours and ten minutes after the fetus was shelled out of the amnion.

This fetus was very sensitive to the bristle touched to snout, body, sides, rump, and dorsum of forearm and paw. It was less sensitive on the hindlimbs and abdomen. The tail was not sensitive.

RAT 51

Date of Insemination: Jan. 8, 1926, 4:03 P.M.

Date of Experiment: Jan. 25, 1926, 3:03 P.M.

Age at Beginning of Operation: 407 hours.

Fetus 1

Age at Beginning of Observation: 407 hours 53 minutes.

Time under Observation: 3 hours 28 minutes.

C-R Length in Ringer's Solution: 16 mm. early measure;
17 mm. late measure.

3:56. Fetus 1 shelled out of the uterus and amnion.
P.M.

4:02. Spontaneous movements observed, consisting of alternate lateral flexion of the trunk, rump and head; flexion and extension of the forearm of the left forelimb; ventral flexion of the rump; extension of the head; abduction of the left hindlimb.

- 4:05. Observed head extension and mouth opening with tongue movement--three times.
- 4:07. Vigorous alternate lateral flexion of the trunk to right and left with head extension, mouth opening and tongue movement.
- 4:12. The bristle touched to the snout, either side, evoked head extension with mouth and tongue movements; at times lateral flexion of the trunk and rump of the opposite side. At times there occurred only forelimb forward and backward movement and flexion and extension of the forearm. Bristle touched to the sides evoked forelimb forward and backward movement with flexion and extension of the forearm, also lateral flexion of the trunk and rump of the same side touched.
- 4:15. Vigorous spontaneous head extension, lateral flexion of the trunk with right forelimb reaching, or extended out (laterally), and then moving backward.
- 4:17. Observed a prolonged (about 10 seconds) complex movement, that involved head extension with tongue movement, and also lateral flexion of the trunk and rump followed by ventral flexion of the rump and the characteristic forelimb reaching or extension and backward movement.

The mouth and tongue movement occurred with the head extension and backward reaching or extension movement of the right front limb.

- 4:22. This fetus seems to be sensitive all over, except the head over the forebrain, and the eye, but the back, rump, sides, belly, hindlimbs and forelimbs are very sensitive.
- 4:24. C.R.L. 16.5 mm. Spontaneous movements consisting of head extension; rump ventral flexion; forelimb flexion and extension of the forearm and forward and backward movement of the forelimb as a whole were noted.
- 4:27. Touched the skin over the liver and on the right side with the bristle and the response was a weak contraction of the skin, that "pulled against" the rump but did not move the rump, and at the same time the right forelimb moved laterally and backward. Observed that the rump ventral flexion was at times so vigorous that it moved the whole head and forelimb region ventrally and with a jerk. Temperature 35.5° C.
- 4:47. Clamping the umbilical cord with the tissue forceps evoked in a very short time vigorous movements.
- 5:05. Head extension with tongue protrusion observed.

- 5:07. Maintained lateral flexion of the trunk which was of the right side; the fetus is lying on the left side in the net.
- 5:10. Temperature of the bath 37° C.
- 5:20. Spontaneous movement observed.
- 5:24. Very active spontaneously. These movements were: head extension; lateral flexion of the trunk and head; head extension with rotation, and sometimes followed by mouth opening and tongue movements; rump ventral flexion and quick head extension; flexion and extension of the forearms; forward and backward movement of the forelimbs; abduction and adduction of the hindlimbs; lateral flexion of the rump; alternate lateral flexion of the trunk, rump and head; flexion of the head on the belly.
- 5:34. Temperature 36° C.
- 5:39. Fetus 1 is very active and is continually displaying spontaneous movements, especially alternate lateral flexion of the trunk which at times is maintained lateral flexion of the trunk and persists as a single contraction for three or four seconds. This maintained lateral flexion is associated with head extension with rotation of the head away from the side of the maintained lateral flexion of the trunk. At this time

the forelimb of the same side, in which lateral flexion of the trunk is occurring, reaches forward and then moves backward. This completes the movement.

5:55. Spontaneous movements observed.

6:02. Responded to bristle stroked over the right or left side, and the response was feeble lateral flexion of the trunk of the same side touched with backward movement of the forelimb of the same side touched. Repeating the bristle stroke over the same side in each case evoked much greater movement, so that the fetus would exhibit nearly all of the movements as a response, each movement in turn.

6:10. Movements observed were as follows: 1) lateral flexion of the head, trunk and rump; 2) alternate lateral flexion of the trunk, rump and head; 3) abduction and adduction of the hindlimbs usually associated with the lateral rump flexion; 4) forward and backward movement of the forelimbs; 5) flexion and extension of the forearm; 6) head extension, quick; 7) rotation of the head; 8) mouth opening and closure; 9) tongue protrusion; 10) ventral flexion of the rump, which is more common than rump extension, head flexion

bringing the head over the abdomen (approximately); 11) maintained lateral flexion of the trunk; 12) extension backward of the whole limb; 13) extension of the rump; 14) flexion of the paw; 15) independent hindlimb abduction movement; 16) contraction of the abdomen, probably rump ventral flexion, which causes the region over the liver to become pale; 17) skin contraction.

The fetuses are very sensitive to the probe, the bristle or the hair touched lightly on the snout. The response is usually head extension with rotation, but it may be lateral flexion of the head or trunk away from the side touched and then head extension may occur. With the movements are forward and backward forelimb movement.

The fetuses are sensitive on the sides of the body, rump and abdomen, but not over the fore-brain region or the eye. Spontaneous movements are almost continuous. The periods of rest are brief. The spontaneous movements may be vigorous, such as maintained lateral flexion of the trunk. The flexion and extension of the forearm or paw alone may occur independently. But usually these movements

are involved with trunk lateral flexion, rump ventral flexion, or head extension. Head extension and rump ventral flexion movements periodically occur.

6:40. Tongue movements noted. Fetus spontaneously active and easily roused. Temperature 35.5° C.

6:42. Clamping the umbilical cord with the tissue forceps evoked after three or four seconds vigorous alternate lateral flexion movements of the trunk with forelimb movement. It might also evoke mouth opening and tongue movements.

6:50. Spontaneously active, exhibiting some vigorous quick head extension with flexion and extension of the forearm and forward and backward movement of the front limbs. Fairly pronounced maintained lateral flexion of the trunk. A tongue movement just observed.

7:01. Have observed many responses and spontaneous movements of Fetus 1. Temperature 35.5° to 36° C.

Have observed quick head extension with rump ventral flexion and during this complex movement there occurred three rapid mouth openings and closures with a tongue movement of protrusion and retraction. The forelimb moved backward, only once, during the time that the

head was in extension. The whole complex act is very quick. It was observed three times in this fetus.

- 7:15. Mother rat has been very calm for the past fifteen minutes. Spontaneous movements of the fetus noted; they consisted of: tongue movements; head extension; rump ventral flexion; lateral flexion of the trunk and head; forward and backward movement of the forelimb; flexion and extension of the forearm; hindlimb abduction.
- 7:20. C.R.L. 17 mm. plus in salt solution. Into Bouin's Solution. Ligated the umbilical cord before cutting him out. Movements followed the ligation of the umbilical cord.
- 7:24. No more fetuses to examine.

PROTOCOLSLater stagesRAT 36

Date of Insemination: Nov. 13, 1925, 4:20 P.M.

Date of Experiment: Dec. 1, 1925, 12:11 P.M.

Age at Beginning of Operation: 427 hours 51 minutes.

Fetus 1

Age at Beginning of Observation: 428 hours 18 minutes.

Time under Observation: 5 hours 19 minutes.

C-R Length in Ringer's Solution: 20 mm. late measure.

12:38. Fetus 1 is in the chorion. Noticed movements
P.M.

during the shelling-out procedure.

1:10. Have shelled out Fetus 1 from the amnion.

1:54. Temperature of the bath 37.5° C. Have observed the movements of Fetuses 1 and 2. The response to touching the snout with flat side of the bone seeker was a complex movement with extreme maintained head extension and allied with more or less coordinated forelimb movement. The rump is in the meantime rotating laterally, the trunk flexing laterally, with occasional aperiodical vigorous ventral flexion and extension movements of the rump. The tail movement is closely associated with the rump movement. At times the forelimbs,

sometimes the left, at other times the right forelimb, flex forward and dorsally so that the paw is at the level of the ear. At times both right and left forelimbs do this at the same time. Have observed in Fetuses 1 and 2 that the left forelimb and left hindlimb during a ventral flexion of the rump actually touch each other on the paws.

- 2:58. Fetus 1 is pink in color.
- 3:14. Activity has been, and still is, almost constant. The other horn of the uterus is now exposed and have noticed the movements of three fetuses through the wall.
- 3:22. Fetuses 1 and 4 when stroked over the snout with a hair from my head gave a decided head extension with backward movement of both forelimbs. The same responses may be obtained or evoked by the horsehair bristle.
- 3:27. Again a response, which was as described for the human hair. Stroking over the snout, flank, sides, forelimbs and hindlimbs evoked the same responses as were evoked by stroking with the horsehair. Temperature of the bath 37.5° C. and has been so for some time, never below 37° nor above 38° . The temperature has been very constant.

- 3:39. Blew some concentrated salt water through a capillary tube into the mouths of Fetuses 1 and 2, and it brought on vigorous mouth opening movements with exaggerated movements of one forelimb, which moved up to the ear, and then the other forelimb did the same. Rump ventral flexion and rump extension also were observed.
- 3:48. The outstanding movement is maintained lateral flexion of the trunk.
- 4:00. In size, C.R.L., and in activity these rats are not 17 days but 18 days and should be considered as such despite the data in timing.
- 4:02. Fetuses 1 and 4 are still exhibiting posture attempts.
- 4:12. Fetus 1 when stroked over the snout with the human hair responded with head extension and this movement was rapid and associated with quick mouth opening.
- 4:22. Forward movement of the right hindlimb as a whole, without any apparent rump movement, was observed. Tail straightening without apparent rump movement, contraction of the skin over the abdomen and back, head extension which was rapid, and backward kicking of both hindlimbs were observed. Rapid head extension with

mouth opening and tongue movements were easily evoked by means of the human hair stroked across the mouth of the fetus. It is so outstanding that it cannot be taken as a spontaneous movement.

- 4:41. Mother rat restless. Gave ether.
- 4:48. Have observed the tongue movements that occurred when the bone probe was held on the snout.
- 4:57. Noted again the same response to the human hair stroked across the mouth, and when the stroking was continued it aroused the fetus to complete and total activity.
- 5:08. The fetuses are very excitable and responded very vigorously when touched by the human hair. The hair is 4 mm. long and is attached to the bone probe by paraffine. It appears that the mouth opens only at the time when the hair touches the tongue. The forelimb movement is not coordinated with head movements, or trunk movements, in such a way as to accomplish any definite purpose or end. By this I mean that all the (forelimb movements, together with other movements, fail to bring about any more comfortable or desirable posture, since in no position does the fetus

rest. When the fetus lies on the one side in the net, then the lateral flexion of the trunk is of the free or opposite side. If it is turned it may for a minute or two continue with these contractions but eventually the contraction is again of the free side.

- 5:22. Temperature of the bath is 38° C. Fetus 1 is rather quiet; only for a short period.
- 5:34. Frequent backward movements of all four limbs at the same time were observed, but the hindlimb movement was associated with rump extension, so that it was impossible to tell whether it was an independent movement of the hindlimbs or a movement of the rump, the tail straightened out at this time and the head extended, so that the whole act was rapid and forceful.
- 5:46. Temperature of the bath is 37.5° C. Fetus 1 is not so active, but still responds spontaneously and when touched with the bristle or bone seeker.
- 5:57. Fetus 1 is not spontaneously active. He is still pink. Not so sensitive; failed to respond to touch of bristle.
- 6:00. Cut out into Bouin's Solution. C.R.L. 20 mm.

RAT 49

Date of Insemination: Dec. 29, 1925, 4:54 P.M.

Date of Experiment: Jan. 17, 1926, 10:57 A.M.

Age at Beginning of Operation: 450 hours 3 minutes.

Fetus 1

Age at Beginning of Observation: 450 hours 43 minutes.

Time under Observation: 2 hours 25 minutes.

C-R Length in Ringer's Solution: 25 mm. late measure.

11:32. Have exposed both horns of the uterus. There
A.M.

are 7 fetuses in the right horn and 5 fetuses
in the left horn. The fetuses are large.

11:35. Fetus 1 shelled out from the uterus.

11:37. Fetus 1 shelled out of the amnion. Observed
spontaneous head extension and rump extension
with hindlimb kicking backward, also mouth
opening and tongue movements.

12:15. The movements in Fetuses 1, 3, 4, 5, are most
commonly quick head extension with mouth open-
ing and tongue protrusion, which is often
followed immediately by rump extension and
kicking backward of the hindlimbs. Stimu-
lation of the snout with the bristle evoked
quick head extension with rotation slightly
away from side touched, and this was immedi-
ately followed by rapid forelimb movement

hindlimbs or forelimbs--was observed. Temperature of the bath 37.5° C.

- 1:15. Now the posture attempt is exceedingly marked. Fetus 1 first tried a maintained left-side posture attempt, then after a few minutes it was on the right side.
- 1:35. Mother rat is very calm. Breathing vigorous, but the metal dam prevents nearly all of the oscillations in the half of the bath where the fetuses are located. The fetuses in the uterus are active occasionally.
- 1:40. The movement in Fetus 1 has been continuous for 25 minutes; in the others there is often some rest, but they are very active.
- 1:46. Fetus 1 is quiet. But he was easily aroused by a light touch with bristle to the right side of the snout. Temperature of the bath 37° C.
- 1:50. Fetus 1 is active again. Mother is breathing noisily.
- 1:55. Mother rat is dying. Fetus 1 exhibited very vigorous alternate lateral flexion of the trunk.
- 1:58. No spontaneous movements. Rat nearly dead.
- 2:00. Mother rat dead. No spontaneous movements of fetuses. No ether to mother. Spontaneous lateral trunk and head flexions of the right

alternating with each other (right-left) toward and away from snout.

12:35. Fetus 1 is very active spontaneously, and vigorous maintained head extension and mouth opening with tongue protrusion which was held for four seconds or more was observed. There was also some maintained lateral flexion of the trunk to the right with rump lateral flexion aperiodically emphasizing the movement with added vigorous contractions to the right. The mother rat is now in the proper condition, which appears after an hour or an hour and a half from the beginning of the experiment, and very little ether is needed. At this time the fetuses become exceptionally active. Temperature of the bath 37.5° C.

12:55. The vigorous maintained posture movements are especially prominent in Fetuses 1 and 3; all of the fetuses now are very active spontaneously and are exceptionally responsive to tactile stimulation with bristle, probe or human hair. Skin contraction over the rump and abdomen was a marked response to very light touch with bristle or human hair in all the fetuses. Often independent movement of flexion and extension of the limbs--either

side noted in Fetus 1. Spontaneous lateral trunk and forelimb movements observed.

2:02. Fetus 1 C.R.L. 25 mm. Cut out into Bouin's.

Simple movements exhibited by this fetus recorded in tabular form:

Extension of the head.

Alternate lateral flexion of the head.

Flexion of the head was a definite movement.

Rotation of the head.

Maintained extension of the head.

Mouth opening and closure.

Tongue protrusion and retraction.

Maintained tongue protrusion.

Lateral flexion of the trunk.

Alternate lateral flexion of the trunk.

Maintained lateral flexion of the trunk.

Maintained lateral flexion of the trunk with
maintained rotation of the trunk.

Rotation of trunk to right or left.

Extension of trunk.

Flexion of trunk.

Lateral flexion of rump.

Alternate lateral flexion of rump.

Rotation of rump to right or left side.

Flexion of rump.

Extension of rump.

Maintained flexion of rump.

Flexion of forearm.

Extension of forearm.

Flexion and extension of paw.

Backward and forward forelimb movement.

Independent movement of forelimb as a whole.

Abduction and adduction of the forelimb as
a whole.

Alternate right and left forelimb forward
and backward movement.

Forward and backward movement of forelimbs,
both together.

Maintained extension of one forelimb, flexion
at elbow of the other.

Movement backward of hindlimb.

Extension of hindlimb, as a whole.

Flexion and extension of hindlimb.

Adduction and abduction of hindlimb.

Extension of tail.

Skin contraction over lateral side of back,
near the rump.

Quick movements, probably constriction move-
ments of the thorax and abdomen.

RAT 73

Date of Insemination: April 12, 1926, 2:25 P.M.

Date of Experiment: May 2, 1926, 11:49 A.M.

Age at Beginning of Operation: 477 hours 24 minutes.

Fetus 2

Age at Beginning of Observation: 478 hours 20 minutes.

Time under Observation: 2 hours 30 minutes.

C-R Length in Ringer's Solution: 30.5 mm.

12:45. Shelled out Fetus 2 from uterus and amnion.
P.M.

1:45. Have been watching Fetus 2 but no gasping or respiratory movements were observed. Constricted the umbilical cord and vessels with the tissue forceps and about one-half minute later the snout, skin over belly and flanks were prodded. Vigorous protrusion of its long tongue ten times, and vigorous mouth opening followed. Have noted vibrissal reflex, which consisted of a movement upward of the vibrissal area; this response occurred when the vibrissal area was touched by the bristle, and was of the side touched. Vigorous spontaneous movements of various kinds occurred at times. The forelimb and hindlimb movements were quick. The mouth movements consisted of not only opening but

closure. They were evoked by stroking the tongue and lower jaw with the bristle. The sensitivity of the lips was very marked. The lips were the only place that stimulation with the bristle was really effective in evoking mouth movements. The response consisted of quick head extension and flexion, rapid mouth opening and closure with tongue movement, and forelimb movements. The movement of the forelimb was forward and backward, but very quick. No eyelid reflex was observed. Stroking skin over back with bristle evoked skin contractions and when continued for 6 for 7 strokes evoked lateral flexion of the trunk of the side touched and forelimb movements.

2:12. C.R.L. 30.5 mm.

2:50. Spontaneous posture movement occurred without interruption. All of these fetuses are exceedingly sensitive to bristle touched to the lips or the snout. Extreme protrusion of the tongue was observed in all of the fetuses. During maintained contraction of the trunk and head extension with rotation, rump rotation in a direction opposite to that of the head occurs to such an extent that the rump is

nearly, though not quite, at right angles to the median sagittal plane.

3:15. Ligated umbilical cord. About fifty vigorous alternate lateral flexion movements followed, and they were associated with vigorous forelimb movements. Gasping movements were noted. Gasping, trunk, and forelimb movements occurred when the fetus was exposed to the air. Into Bouin's Solution.

IV. DEVELOPMENT OF MOVEMENT

The following description is written on the basis of the protocols, which, referred to in the text by their designating letters and numbers, are found in Section III. The fetuses have been numbered according to the following plan: the capital letter "R" followed by the number indicates the litter or rat, and the capital letter "F" followed by the number indicates the fetus; for example, R40 F1 refers to fetus 1 from rat or litter 40.

The non-motile fetuses

Fetuses R40 F1, F2, F3, F4, F5, F6, F7, F8, F9, and F10, as well as fetuses R32 F1, F2, F3, F5, F6, and F7 were non-motile fetuses, and also the youngest fetuses that were studied.

The litter age of the fetuses of R40 was 364 hours and 20 minutes, and for all the fetuses the crown-rump length was 12 mm. The actual age of fetus R40 F1, the first fetus observed in this litter, was 365 hours, and the actual age of fetus R40 F10, the last fetus exposed and observed in this experiment, was 367 hours and 30 minutes after insemination.

These fetuses were under observation in series for 10, 16, 7, 10, 13, 40, 10, 5, 4, and 12

minutes respectively. All these fetuses, so far as could be determined, were viable. Nevertheless, they exhibited no movement other than the heart beat, despite tactile stimulation of the snout or the body with bone probe and bristle. No spontaneous movements were observed, and fetus R40 F10 failed to respond even though the trachea of the mother rat was constricted sufficiently to choke her to the extent that it caused her to struggle for air. The temperature of the Ringer's solution was 37.5° C. and did not fluctuate more than a half a degree at any time. Very little ether was needed to keep the mother rat calm. Under these conditions, it seems reasonable to conclude that the fetuses of R40 were not capable of movement and that they were, therefore, non-motile fetuses.

The fetuses of R32--F1, F2, F3, F5, F6, and F7--were older and larger than those of R40. The litter age of these fetuses was 374 hours and 25 minutes, and the crown-rump length of all was 13 mm. These fetuses were under observation for 30, 33, 15, 32, 43, and 45 minutes, respectively. Although all of these fetuses were viable they exhibited neither spontaneous movements nor tactile responses. Even strong induced electrical current failed to evoke a response in fetus R32 F5. The heart beat was the only movement observed.

Early motile stage

The first, or earliest detectable, movement of the albino rat fetus was a lateral flexion of the head. It was exhibited by fetus R32 F8, and was evoked by touching the vibrissal region of one side of the snout of the fetus with the bone probe. The movement was slow and feeble, and only two responses were elicited during the time this fetus was under observation.

Fetus R32 F9 was probably a trifle more excitable, for tactile stimulation of the snout with the bristle evoked a definite lateral flexion of the head to the left side, which was followed by passive backward movement of the right forelimb, and stimulation of the snout with the bone probe evoked a feeble lateral flexion of the head. Fetus R32 F10, however, responded only once to stimulation of the snout with the bristle, and the response, which was a feeble movement, consisted of lateral flexion of the head. The litter age of these fetuses was 374 hours 25 minutes, their crown-rump length was 13.5 mm.; the actual age of F8 was 378 hours 18 minutes, the actual age of F9 was 379 hours 8 minutes, and the actual age of F10 was 380 hours 15 minutes. Fetuses R32 F8, F9, and F10 were the youngest fetuses to exhibit movement, and they were all at approximately the same stage of development.

In the same litter, as mentioned above, there were six viable non-motile fetuses and one non-viable fetus (R32 F4, protocol not included in Section III). These fetuses measured 13 mm. crown-rump length. Since these fetuses exhibited no movements, they have been classified as non-motile fetuses.

There is no doubt that the responses of fetuses F8, F9, and F10 were due to excitation of the afferent nerves of the snout, for the movement followed immediately after the vibrissal region of the one side of the snout was touched by the bone probe or the bristle. The response observed was a passive movement of the head to the side away from the side touched by the bone probe or the bristle, and was followed by movement of the forelimb of the side touched.

Spontaneous movements were not observed in any of the fetuses of R32. But fetus R24 F1--whose litter age was 377 hours 52 minutes, actual age 378 hours 32 minutes, and crown-rump length was 13.5 to 14 mm.--exhibited one spontaneous movement, which was lateral flexion of the head to the right side. Of all the specimens observed this was the first or earliest to give indication of spontaneous movement.

Besides the spontaneous movement mentioned, fetus R24 F1 exhibited six crossed lateral flexion movements of the head in response to stimulation, with the

bone probe, of the vibrissal region of one side of the snout, and three same-side lateral flexion movements of the head when the vibrissal region of one side of the snout was stimulated with the bristle. The movement of the front limb as a whole was doubtful or passive.

It is possible that this fetus was slightly more developed than fetuses R32 F8, F9, and F10, but the difference in age was very small and in crown-rump length there was no difference.

Fetus R24 F5 exhibited only one crossed lateral flexion movement of the head when the snout was touched by the bristle. Fetus R24 F6 exhibited seven crossed lateral flexion movements of the head, when the snout was touched by the bristle. No spontaneous movements were recorded for these two fetuses. The crown-rump length of fetuses R24 F5 and F6 was 14 mm. They were a little larger than the other fetuses mentioned.

In all of the six motile fetuses observed the movement or response was feeble, slow and definite.

The single spontaneous movement exhibited by fetus R24 F1 did not differ in kind from the tactile responses of this fetus. The tactile responses were more in evidence than the spontaneous movements. Nevertheless, the total reaction of these very young rat fetuses, whether it was a tactile response or a spontaneous movement, consisted of passive lateral flexion

of the head, associated with doubtful or passive movement of the forelimb.

The movements of these six motile fetuses do not demonstrate a finely graded series of stages of development, but collectively they show the kind and nature of the earliest movements of the albino rat fetus.

Further development of movement is shown by fetuses R27 F1 and F2, R48 F4 and F6, R70 F1, F2, and F4, R71 F1, R34 F7, R38 F1, F2, and F4. The litter ages of these fetuses ranged from 378 hours 40 minutes to 388 hours, and the crown-rump lengths from 13.5 to 14 mm. All of these fetuses were slightly more developed than the six motile fetuses just described.

In all these motile fetuses the dominant movement was lateral flexion of the head, trunk or rump to one side, for it was observed in all of the fetuses and was the outstanding movement. In some of the fetuses lateral flexion of the head, trunk and rump was a relatively vigorous movement (R27 F2, R71 F1, R34 F7); in others, however, it was rather feeble (R27 F1, R70 F2). Tactile stimulation of the vibrissal region of the snout evoked lateral flexion of the head, trunk and rump in all of these fetuses.

Lateral flexion of the head, trunk or rump was of either the right or left side in all of the

fetuses of this group. For tactile stimulation of the vibrissal region of one side of the snout in most of these fetuses evoked lateral flexion of the head, trunk and rump to the opposite side. Alternate lateral flexion of the head, trunk and rump was exhibited by fetuses R27 F1 and F2, R48 F4 and F6, R71 F1, R38 F2 and F4.

Lateral flexion of the head, trunk or rump was often associated with movement of the forelimb (see fetuses R27 F2, R48 F4 and F6, R70 F1, F2, and F4, R71 F1, R38 F2 and F4.) There was no forelimb movement recorded for fetuses R27 F1 and R38 F1. The forelimb movement in the youngest or least developed fetuses, as, for example, in R32 F9, probably was passive abduction backward of the forelimb as a whole of the side opposite from that of the trunk contraction, and, in this case, it was probably caused by the contraction of the muscle cells of the trunk. In some of the slightly more developed fetuses, there was actual forelimb movement which consisted of abduction backward and forward of the forelimb as a whole of the side opposite that of the contraction of the trunk. The forelimb of the side of the contraction apparently moved slightly forward toward the snout. Undoubtedly the sequence of the movement of the forelimbs is determined or dominated by the lateral flexion of the

trunk.

The position of the forelimbs at this age is an important consideration. They are short structures with shovel-shaped feet; the toes are not yet separated. There is no external indication of flexibility in the parts of the forelimb which later will become the wrist and elbow joints. The palmar surface of the paw is nearly parallel with the body wall near it in the very youngest fetuses of this group, and in those slightly more developed the forelimb has rotated slightly and the palmar surface of the paw is oblique to the lateral body wall.

The exact time relations between contraction which causes lateral flexion of the trunk and the movement of the forelimb are not as yet determined. It seems that forelimb abduction movement occurred immediately after the beginning of the contraction of the opposite side of the trunk, and that the backward movement of the forelimb was due to the tension or pull imparted to it by the trunk contraction. At this stage both forelimbs never move backward or abduct together.

Spontaneous movements, as well as tactile responses, often included forelimb movement; for instances of forelimb abduction backward and forward movement, or simply backward and forward movement,

were extensively recorded. But lateral flexion movements of the head, trunk, and rump, and forelimb movements were the most definite and characteristic movements of these fetuses, and, in fact, of all of the fetuses of the early motile stage.

Lateral flexion of the trunk or the rump was associated with abduction of the hindlimb as a whole, but the latter movement was of rare occurrence and was feeble. Hindlimb abduction movement was noted for fetuses R71 F1 and R38 F2. There is no doubt that the movement was abduction of the hindlimb as a whole.

The hindlimbs at this stage of development are short, relatively thick structures and the plantar surfaces of the shovel-shaped feet which face each other are parallel to the median plane. The feet are not in direct apposition to each other, for the tail, which curves ventrally, lies between the two hindlimbs. There is no indication of joints and the toes are not separated. The hindlimbs are less developed than the forelimbs. Adduction of the hindlimb, which obviously must follow abduction, was a passive movement. The hindlimb movement occurs on the same side as the lateral flexion of the rump. It is, in this stage, a part of the rump movement. Independent hindlimb movement was not observed at this age. It is possible that feeble con-

tractions of the trunk, imperceptible to the eye, might impart movement to the hindlimb and that, due to its shape and position, the hindlimb would, like a lever, amplify these feeble movements. In such a case, the impression would be that hindlimb abduction movement had occurred. Such movement, however, would be extremely feeble and, in this respect, different from the actual hindlimb abduction movement that was observed.

All of these fetuses at times showed variations in kind, amount, and strength of the movement. The total response or reaction was dependent on their development, their viability and irritability. Fetuses R71 F1, 384 hours 11 minutes, and R38 F2, 338 hours, were the only fetuses for which the total reaction included all of the movements described above.

The last step in the development of movement of fetuses of the early motile stage is best shown by the following fetuses: R62 F5, F6, and F7, whose litter age was 386 hours; R58 F3, F4, and F5, whose litter age was 390 hours 6 minutes. All of these fetuses were 14.5 mm. in crown-rump length. The external appearance of these fetuses clearly shows that they were more developed than those previously described. They were larger and the forelimbs showed a slight increase in length, especially of the forearm. The toes

of the front feet were not separated. The hindlimbs were nearly the same, probably a trifle longer.

The amount of movements, that is, the number of tactile responses and spontaneous movements which are recorded for these fetuses, shows an increase in amount of movement over that of the fetuses previously described. The inference from the frequent recurrence of the word "vigorous" in the original notes likewise would be that the movements were more vigorous or stronger than those of the early fetuses. The dominant movement of these fetuses was lateral flexion of the head, trunk or rump and the alternate sequence of this movement was prominent, for it occurred often in every fetus. The duration of an alternate lateral flexion movement was usually three contractions, that is to say, to the left, right and left sides, or to the right, left and right sides. The forelimb movement, also, was more developed, for flexion and extension of the forearm was observed in all of these fetuses except R58 F4. It is possible that flexion and extension of the forearm did occur in this fetus but was not recorded. Whenever the movements of the fetus are many, the chances of failure to observe and record a new movement are proportionately increased. Complexity of behavior is obviously more difficult to observe and record in detail than simplicity of behavior.

It was observed, however, that the forelimb movement was associated with the lateral flexion of the head, trunk, or rump, despite the acquisition of the new movement of flexion and extension of the forearm. A description of the sequence of the forelimb movement is given for fetus R62 F7 (observation at 10:39 P.M.): "The forelimbs are very adept and paddle backward and forward with abduction and are associated with the head and trunk lateral flexion." Again, the observation for fetus R58 F3 at 10:14 P.M.: "Noted spontaneous alternate lateral flexion of the trunk with abduction and backward movement of the forelimb which is at times very quick and appears like 'reaching' or extension and flexion;" again, in the same fetus at 10:30 P.M.: "The forelimb 'reaches' or extends backward during the height of the lateral trunk flexion, after which it pulls back unsteadily." Again, same fetus: "The forelimbs alternating with each other." Again, in fetus R58 F4, at 9:38 P.M.: "The movement of the forelimb is decidedly abduction to the side and due to the shape and position of the forelimb the movement is backward and of the limb as a whole."

All of which shows that the exact rhythm of movement of the two forelimbs and the exact time relation to the dominant lateral flexion of the head or trunk is, as yet, undetermined. But the forelimb move-

ment is associated with lateral flexion of the head or trunk and dominated by the latter. The former is still a part of the lateral flexion of the head or trunk and is not demarcated by an independent rhythm of its own, despite the fact that the forelimb has acquired a movement of its own, which is flexion and extension of the forearm. It seems that the right forelimb is allied with the left forelimb through the trunk, and not directly, for backward or forward movement of both forelimbs simultaneously was not observed.

The movements of the forelimbs greatly exceed those of the hindlimbs. Every fetus of this group except R58 F4 exhibited hindlimb abduction movement. But it was a feeble and only occasional movement, and it was associated with the lateral flexion of the trunk or rather the rump. It followed along with the rump movement. The hindlimb abduction movement in these fetuses showed very little, if any, development.

Although the dominant movement consisted of a lateral flexion of the head, trunk, or rump, which was exhibited by all of the motile fetuses, the attainment by the fetus of all of the movements described above and exhibited as the maximum capacity of movement signified that the fetus had reached the fullest possible extent of development of movement at this stage.

The dorso-ventral extension-flexion stage

From the 378th hour to the 390th hour after insemination the development of movement of the fetus as shown by the increase in kind, amount, and strength, has been closely correlated with litter age and crown-rump length of the fetus. From the 390th hour to the 408th hour there is no close correlation of fetal movements with either crown-rump length or litter age. For the variations in crown-rump length of the fetuses from the same litter, or fetuses from another litter of the same litter age, may be as much as two millimeters or more. Another variation is shown by the fetuses R50 F5 and R61 F2. The litter age of the former was 390 hours and the litter age of the latter was 396 hours. The crown-rump length of each fetus was 15 mm., which shows that an increase of six hours in litter age does not necessarily mean an increase in crown-rump length. On the other hand, an increase of three hours in litter age of the fetus may show an increase of one-half millimeter in crown-rump length. This is illustrated by fetuses R69 F1 and F7. The litter age of these fetuses was 393 hours, and the crown-rump length was 15.5 mm. Because of such variations in litter age and crown-rump length the description of the development of movement of the rat fetus cannot, at this time, be correlated

statistically with litter age and crown-rump length. Nevertheless, the results already attained indicate that such correlation is possible by the extension of observations to a sufficient number of individual fetuses from many litters.

The protocols of the fetuses R50 F5, R69 F1 and F7, R61 F2 and F3, and R56 F2 nevertheless illustrate the movements of the rat fetuses of 390 hours, 393 hours, 396 hours, and 399 hours. Since the movements of each fetus were typical of those of all members of the same litter, only one fetus from each litter will be considered.

Fetus R50 F5 is the youngest of this group, for it was 390 hours litter age, and 15 mm. crown-rump length. Its external appearance when compared with that of fetus R58 F3 showed no difference except that it was a trifle larger than R58 F3.

There was no difference in external appearance or crown-rump length of fetus R50 F5 and fetuses R61 F2 and F3, although the latter were 396 hours litter age, that is to say, six hours older. Fetuses R69 F1 and F7, however, were larger, and also three hours older, than fetus R50 F5, but three hours younger than fetuses R61 F2 and F3.

Fetus R56 F2 was the same crown-rump length as fetus R50 F5, namely, 15 mm., but the litter age of

this fetus was 398 hours and 34 minutes. Obviously, this fetus was the oldest, and was more developed than any of the other fetuses, despite the fact that it was the same crown-rump length as fetuses R50 F5, R61 F2 and F3, and one-half millimeter less than fetuses R69 F1 and F7.

The same kinds of movements exhibited by the fetus at the end of the early motile stage were exhibited by these fetuses, but the movements were stronger and of longer duration.

Alternate lateral flexion of the trunk, rump and head was more vigorous and the duration of this movement was increased. Fetus R50 F5 exhibited nine alternate lateral flexions of the trunk during a period of spontaneous activity, and in fetus R69 F7 the spontaneous activity was almost continuous for eight minutes. Also, in fetus R56 F2 alternate lateral flexion of the trunk and rump was the most vigorous of all of the movements. Alternate lateral flexion of the trunk was the dominant movement of these fetuses.

The forelimb movements were more developed, although no new movements of the forelimbs were observed in any of the fetuses. In all of the fetuses the forelimb movements were relatively well-executed and associated with lateral flexion of the trunk during total

activity. Independent forelimb movement was observed in fetus R69 Fl. The forelimb movements were much more developed than the hindlimb movements.

The movement of the hindlimbs was abduction and adduction, and it was associated with lateral flexion of the rump. Increased development of the hindlimb movement was not evident, except that it occurred more often and was not as feeble as the hindlimb movement exhibited by the fetuses of the early motile stage.

The development of movement of the rat fetus between the litter ages 390 hours and 399 hours is shown by the appearance of new movements. These movements were head extension, rump ventral flexion, mouth opening, tongue movements, and maintained lateral flexion of the trunk.

The first new movement mentioned, head extension, was exhibited by all of the fetuses of this group, and it was a quick movement. Often it occurred as the immediate response to tactile stimulation of the snout. When evoked by tactile stimulation of the snout this movement generally preceded lateral flexion of the trunk. Head extension, even after its appearance as the immediate response to tactile stimulation of the snout, did not replace the lateral flexion of the head completely, for the latter movement occurred, especially if the stimulation of the snout was strong.

As mentioned before, lateral flexion of the head was a passive movement of the head due to the lateral flexion of the trunk. During spontaneous activity head extension occurred occasionally at irregular intervals. It was associated with movements of the trunk in this respect, that it preceded or followed lateral flexion of the trunk. Since it was a quick aperiodic movement it interrupted the rhythmic and slower lateral flexion movements of the trunk.

The fact that head extension was exhibited by fetus R50 F5, the youngest and least developed fetus of this group, and that it persisted in all of the fetuses, indicates that this movement marks a new stage of development of movement of the rat fetus. Furthermore, head extension is a movement which can be evoked by tactile stimulation of the snout, and also occurs aperiodically during spontaneous activity. Although it was a movement which occurred aperiodically, it was not an infrequent movement. Head extension, therefore, is the movement which distinguishes or marks the development of this group and also suggests the name "dorso-ventral stage" for this group, because the movement of the head is in a dorso-ventral direction in contrast to the bilateral flexion of the head exhibited in the early motile stage.

Head extension movement marks the extent of development in kind of movement of the fetuses R50 F5

and R61 F2 and F3. The two latter fetuses are of the same stage of development as R50 F5, despite the difference of six hours in litter age.

The rump ventral flexion movement was not exhibited by fetuses R50 F5, R61 F2 and F3. Fetuses R69 F1 and F7 and R56 F2, however, did exhibit rump ventral flexion.

Rump ventral flexion was a quick and vigorous movement. Sometimes it followed lateral flexion of the trunk and rump. At other times rump ventral flexion followed quick head extension. It was not noted as the immediate response to tactile stimulation of the snout. Like head extension, it occurred aperiodically during spontaneous activity.

Rump ventral flexion movement was associated with lateral flexion of the trunk, but like head extension movement it was an aperiodical movement and therefore when it occurred it also interrupted the rhythm of the alternate lateral flexion movements of the trunk.

The appearance of rump ventral flexion movement indicates that the muscles of the ventral abdominal wall can function or contract. Moreover, it is further evidence that the trend of development of movement is at this stage dorso-ventral.

Fetuses R69 F1 and F7 and R56 F2 exhibited also feeble mouth and tongue movements. These movements were closely associated with each other as well as with

head extension movement. Like head extension and rump ventral flexion, the movements of the mouth and tongue were quick, and, besides, they occurred also at irregular intervals during spontaneous activity of the fetus.

The mouth movement consisted of a quick opening of the mouth, and the tongue movement was a protrusion of the tongue while the mouth was opened. The mouth of the fetus at this stage, however, was slightly open in the resting condition, and the tongue was visible, for the lower and the upper jaw were as yet incompletely developed.

Tongue movement without mouth opening movement was observed in some of the fetuses of this stage, and mouth opening without tongue protrusion also was noted for others. Both movements often followed or accompanied quick head extension which was evoked by tactile stimulation of the snout.

It is interesting to note that the four movements just described--i.e., head extension, rump ventral flexion, mouth opening, and tongue protrusion--are quick movements that occur aperiodically during spontaneous activity of the fetus. Although closely allied with each other and associated with the dominant alternate lateral flexion movement of the trunk and more or less associated with forelimb movement, the four former movements interrupt aperiodically the

rhythm of the trunk and forelimb movements. With the appearance of these movements during spontaneous activity the movements of the fetus then resemble those of the new-born rat.

The appearance of maintained lateral flexion of the trunk, which marks another step in the new development of the trunk movement of the rat fetus, was exhibited by fetuses R69 F7 and R56 F2, although less marked or evident for fetus R69 F7 than for fetus R56 F2.

In all of the fetuses of the early motile stage and fetuses R50 F5, R61 F2 and F3, and R69 F1 the movements of the trunk were not held or maintained.

The fetus R69 F7 was the youngest or least developed fetus of this group in which there was any indication of maintained lateral flexion of the trunk. The fetus R56 F2 exhibited several maintained lateral flexion movements of the trunk. The duration of the contraction was two or three seconds. It was noted that the forelimb of the contracted side was extended as a whole and slightly maintained during the maintained lateral flexion of the trunk.

Maintained lateral flexion of the trunk did not occur as the immediate response to tactile stimulation, but was noted during prolonged spontaneous activity and was therefore essentially a spontaneous move-

ment which occurred at the time when the fetus was very active.

The extent of development of movement of the fetus at the 399th hour of gestation was shown by the movement of head rotation which was exhibited by fetus R56 F2 only. It was a turning movement of the head to the side and was modified by head extension. Head extension and rotation of the head occurred as the immediate response to tactile stimulation. Head rotation was not a clearly defined movement.

The movements exhibited by the fetus R56 F2 of the dorso-ventral stage consisted of:

1. Lateral flexion of the head, trunk, and rump.
2. Alternate lateral flexion of the head, trunk, and rump.
3. Forelimb forward and backward movement.
4. Flexion and extension of the forearm.
5. Hindlimb abduction and adduction.
6. Head extension.
7. Rump ventral flexion.
8. Mouth opening.
9. Tongue protrusion.
10. Maintained lateral flexion of the trunk.
11. Slightly maintained backward movement of the forelimb of the same side as the contraction during maintained lateral flexion of the trunk.

12. Head rotation modified by head extension.

Further development of the power of movement of the rat fetus is illustrated by the protocols of fetuses R41 F6, R55 F2, R52 F2, R33 F1, and R51 F1. The litter ages of these fetuses in the order mentioned above were 401 hours and 35 minutes, 404 hours and 15 minutes, 405 hours 12 minutes, 406 hours 32 minutes, and 407 hours. The crown-rump length of the fetuses was 15 mm., 15.5 to 16 mm., 16 mm., 16 mm., and 16 mm. to 17 mm., respectively. No new simple movements were exhibited by the fetuses R41 F6, R55 F2, R52 F2, for the kinds of movements recorded for them were the same as those exhibited by fetus R56 F2. Their movements and those of R33 F1 are, therefore, not described in detail below. Only those observations which indicate further development are included in the description. Finally, however, fetus R51 F1 is described in detail, in order to emphasize the extent of development of the fetus at the end of the sixteenth day, or at the beginning of the seventeenth, after insemination.

Fetus R41 F6 exhibited the same simple movements as fetus R56 F2. An increase in the duration of the maintained lateral flexion of the trunk in the former fetus was observed, for the duration of the maintained lateral flexion of the trunk was three to seven seconds. Every second or so the contraction was

emphasized by an additional contraction of the contracted side to hold or maintain the lateral flexion of the trunk. Likewise the other movements exhibited by fetus R41 F6 were apparently stronger and of more frequent occurrence than those exhibited by fetus R56 F2.

Fetus R55 F2 was a little more developed than either of the two fetuses previously mentioned. The simple movements exhibited by it were of the same kind as those exhibited by fetuses R56 F2 and R41 F6. Rump ventral flexion was a very vigorous movement, in fact, so vigorous that when it occurred the whole head and forelimb region was moved ventrally onto the abdomen. Head flexion may have occurred, but it was not a definite movement. Furthermore, it was associated with vigorous rump ventral flexion. Head extension movement was pronounced and slightly maintained, and associated with quite prolonged mouth opening and tongue movements.

Clamping of the umbilical cord with the tissue forceps evoked mouth opening and tongue movements.

Fetus R52 F2 was very active and exhibited all of the simple movements described for the fetuses R56 F2, R41 F6, and R55 F2. It was observed that rump ventral flexion was so powerful that it raised the whole head and forelimbs up and off the net. The movement was more vigorous than alternate lateral flexion of the

trunk.

During maintained lateral flexion of the trunk the forelimb of the contracted side was extended as a whole, and the extension of the forelimb was maintained. Maintained lateral flexion of the trunk was of frequent occurrence.

Maintained head extension was not observed and head flexion was not recorded. Mouth movement was evoked by prodding inside the mouth of the fetus with a fine rat hair.

The immediate movement in response to tactile stimulation of the snout often was head extension modified by rotation of the head, and the direction of the movement of the head was away from the side touched. Alternate lateral flexion of the trunk sometimes followed this movement of the head.

Fetus R33 F1 was under observation for three hours and ten minutes. During this time it was very active (which demonstrates the increased capacity of the older fetuses to withstand the experimental procedure). The same simple movements exhibited by the younger fetuses of this group were exhibited by fetus R33 F1; and also rump extension.

It is interesting to note that maintained lateral flexion of the trunk was exhibited by this fetus and followed shortly after four drops of ether had been

applied to the mask over the snout of the mother rat. The duration of the maintained lateral flexion of the trunk was about four seconds.

It was noted for fetuses R33 F1 and R51 F1 that during the rump ventral flexion movement the liver region, which is normally of very red color, became pale. This color change was not a simple movement, but it is significant in so far as it indicates that the body may impart the force of its movement to the viscera in the abdomen and cause passive movements, at least, of the latter structures.

The extent of development of movement that may be attained by the rat fetus at the end of the 16th day or the beginning of the 17th day after insemination is illustrated by R51 F1. This fetus was 407 hours of litter age and 408 hours actual age at the time the observation was made. The crown-rump length was 16 mm. early measurement and 17 mm. late measurement. Although no quantitative measurement of the strength of the movements of this fetus was made, it is probable that they were more vigorous or stronger than the movements of any fetus described above. Spontaneous activity was almost continuous from the beginning to the end of the observation, which occurred three hours and twenty-eight minutes later. Tactile stimulation of the snout, shoulder, sides, back, rump, and abdomen readily evoked movement. The

fetus was easily aroused.

The movements of the trunk consisted of lateral flexion, alternate lateral flexion, and maintained lateral flexion. Lateral flexion occurred as the immediate movement in response to tactile stimulation of the shoulder, sides, back and rump of the fetus, and the contraction was on the side which was touched. Alternate lateral flexion occurred during spontaneous activity. At times the movement was quite prolonged, even for ten seconds. During prolonged activity of the fetus alternate lateral flexion was the dominant movement. The forelimb movements were closely associated with alternate lateral flexion of the trunk. Maintained lateral flexion of the trunk, observed during the periods of spontaneous activity, was a vigorous movement and it was noted that the maintained lateral flexion was of the right side when the fetus was lying on the left side in the net. At this stage the posture attempt, which is a complex movement, consisted of: maintained lateral flexion of the trunk with backward movement of the forelimb of the contracted side, and head extension with rotation of the head away from the contracted side. Maintained lateral flexion of the trunk was the dominant movement of the posture attempt.

The movements of the head consisted of head

extension, head rotation and probably slightly maintained head extension. Head flexion and head lateral flexion were not observed as positive movements. Head extension was a common spontaneous movement, and readily evoked by tactile stimulation of the snout. The movement was always very quick and often rapidly repeated three or four times.

At times the immediate response to tactile stimulation was head extension movement modified by rotation of the head away from the side touched. At other times, however, tactile stimulation of one side of the snout evoked lateral flexion of the head which was caused by lateral flexion of the trunk of the side opposite that touched.

Besides head rotation the following movements were closely associated with head extension: mouth opening, tongue protrusion, rump ventral flexion, and maintained lateral flexion of the trunk and rump. Tactile stimulation of the snout evoked head extension followed by mouth opening and tongue protrusion. These were observed also as spontaneous movements. During spontaneous activity head extension and rump ventral flexion occurred and the movement was vigorous. All these movements were quick and vigorous. Rump ventral flexion, however, was even more vigorous than head extension.

Head extension was the most definite movement of the head. Although head rotation was a definite, quick movement, it was nevertheless so closely allied with head extension that it appeared to be a part of this movement. Maintained head extension probably occurred during maintained lateral flexion of the trunk, but the duration of the contraction was not recorded.

The movement of the rump consisted of lateral flexion, alternate lateral flexion, ventral flexion, and rump extension. Lateral flexion and alternate lateral flexion of the rump were essentially a part of the movement of the trunk. But rump ventral flexion and extension are distinct movements of the rump, for when they occur there is no apparent movement of the trunk. Independent lateral flexion of the rump was not noted. Rump extension was a vigorous movement and consisted of a straightening dorsally of the caudal end of the trunk. It was not as frequent as rump ventral flexion. Rump ventral flexion was a quick spontaneous movement. Often it was so vigorous that it moved the whole head and forelimb region ventrally with a jerk. Rump ventral flexion was associated with head extension movement, for both movements occurred simultaneously at irregular intervals during spontaneous activity of the fetus and interrupted the rhythmic alternate lateral

flexion movements of the trunk. Sometimes the one movement preceded the other.

The forelimb movement consisted of forward and backward movement, flexion and extension of the forearm, flexion of the paw and slightly maintained backward movement or extension of the whole limb. The forelimb movements were well-executed. They were associated with the alternate lateral flexion movements of the trunk and at times they appeared to be allied with head extension and rump ventral flexion. The relation of the forelimb movement to maintained lateral flexion of the trunk was mentioned above. The forelimb movements were considerably more developed than the hindlimb movements. Independent forelimb movement occurred.

Forelimb movement was allied with skin contraction, for the forelimb moved backward when the skin over the rump and right side contracted.

The exact sequence of the forelimb movements with those of the trunk and head during activity of the fetus was not determined. But there seemed to be more or less alternate movement of the forelimbs with each other. Besides the alternate lateral flexions of the trunk seemed to influence or dominate the sequence of the movement of the forelimbs.

Backward movement of the forelimbs more or

less together was observed during head extension and rump ventral flexion.

The hindlimb movements consisted of abduction and adduction. They were of frequent occurrence and seemed to be dominated by the rump movement, for they were closely allied with the lateral flexion movements of the rump, but the exact sequence was not determined. The hindlimb movements were not as well developed or as vigorous as the forelimb movements. At best they were crude abduction movements of the hindlimb as a whole. They probably followed in some kind of sequence with the forelimb movements, after the manner of locomotion.

Mouth movements consisted of lowering and raising of the mandible, and they were closely allied with tongue movements. The tongue movements consisted of tongue protrusion and retraction. Both of these movements were of frequent occurrence. They were evoked by tactile stimulation of the snout. They occurred also during spontaneous activity. Generally they were directly associated with head extension. The movements of the mouth and tongue were quick.

Skin contraction was observed as the immediate response to tactile stimulation of the skin over the liver and right side. It was a feeble movement of the skin over the rump, which pulled against the rump

but did not move it. The contraction was associated with backward movement of the forelimb of the side touched or stimulated. During rump ventral flexion movement the liver region, which is usually red in color, became pale. This color change is not a movement, but it suggests that the visceral structures in the abdomen are moved passively by the contractions of the ventral abdominal muscles.

The movements, exhibited at the end of the 16th or beginning of the 17th day, when summarized in tabular form, illustrate concisely the development of movement attainable by the albino rat fetus at this stage.

The movements of the head consisted of:

Head extension - which was slightly maintained during the posture attempt and allied with

Head rotation.

Lateral flexion - was a passive movement caused by lateral flexion of the trunk.

The movements of the trunk consisted of:

Lateral flexion.

Alternate lateral flexion - which was the dominant movement and continuous for long periods.

Maintained lateral flexion - the duration was 3 or 4 seconds.

The movements of the rump consisted of:

Lateral flexion () were essentially part
 Alternate lateral flexion) of trunk movements.

Ventral flexion - was the most powerful of all the
 movements.

Extension - was a vigorous movement.

The movements of the forelimbs consisted of:

Forward and backward movement.

Flexion and extension of the forearm.

Flexion of the paw.

Probable maintained backward extension.

The movements of the hindlimbs consisted of:

Abduction and adduction.

The movements of the mouth consisted of:

Mouth opening and closure or lowering and raising
 of the lower jaw.

The movements of the tongue consisted of:

Protrusion and retraction.

The movement of the skin over the rump consisted of:

A feeble contraction of the skin.

Later stages

A continuation of the description of the movements exhibited by the rat fetus from the 408th hour litter age until birth cannot be presented at this time because the development of these ages has not been sufficiently investigated to justify a detailed description of the litters which were observed.

The protocols of three fetuses, R36 F1 (428 hours litter age and 20 mm. crown-rump length), R49 F1 (450 hours litter age and 25 mm. crown-rump length), and R73 F2 (477 hours litter age and 30.5 mm. crown-rump length), however, have been included because they illustrate the development of movement that may be attained by an eighteen-, a nineteen-, and a 20-day fetus. Furthermore the movements of these fetuses verify to a certain extent some of the observations made for fetuses of the 16th day.

The 18th-day fetus.

All of the movements exhibited by fetus R51 F1 of the 17th day were recorded for fetus R36 F1. Moreover, all of the primitive movements--that is to say, the movements that characterize the early motile stage--were stronger, more frequent, and also more individuated.

The head extension movement at times was vigorous and maintained, and also more or less coordinated

with forelimb movement. At times head extension was quick and associated with mouth opening and tongue movement. The forelimb movements were considerably developed, for at times flexion forward and dorsally which raised the paw to the level of the ear was observed.

During rump extension the hindlimbs were observed to move backward quickly, and tail straightening movement was also observed.

The hindlimbs were considerably more developed in fetus R36 F1 than in fetus R51 F1, but they did not exceed the forelimbs in development.

The rump movements were vigorous and rotation of the rump was recorded. Rump ventral flexion and rump extension were aperiodic movements and they interrupted the maintained lateral flexion of the trunk when they occurred. Maintained lateral flexion of the trunk was the outstanding movement.

The complex movement or posture attempt was of frequent occurrence, and during spontaneous activity it appeared to be the only movement that might be construed as purposive. When the fetus lay on the one side in the net the lateral flexion of the trunk was on the free or opposite side. When the fetus was turned over it continued for a minute or two with the same contractions, but eventually the contraction was again on the free side.

This fetus was decidedly viable, for it was shelled out and under observation for five hours and eighteen minutes. During most of this time it was very active. Mouth and tongue movements were of frequent occurrence. Skin contraction was also noted. The new movements exhibited by this fetus were rotation of the rump, extension of the tail, and backward movement of the hindlimbs. The fetus was sensitive to the probe, the bristle, and the hair stroked over the snout, mouth, shoulder, back, flanks, and forelimbs and hindlimbs.

The 19th-day fetus.

Fetus R49 F1, as mentioned above, was a nineteen-day fetus. The extent of development of movement attained by this fetus is best shown by the number of new movements it exhibited. All of the different kinds of movements are tabulated on page 125 in the protocol section. The following movements were the new movements this fetus exhibited: ventral flexion of the head was a discrete movement; tongue protrusion was maintained at times; maintained lateral flexion with maintained rotation of the trunk was noted; rotation of the trunk and rump to the right or left side; maintained extension of one forelimb and flexion at the elbow of the other forelimb; extension of the hindlimb as a whole; flexion and extension of the hindlimb;

quick movements, probably constriction movements, of the thorax and abdomen. The posture attempt was especially prominent.

The movements of this fetus were very vigorous and they were continuous for twenty-five minutes. It is obvious that movements of this fetus were stronger and more individuated than the movements of fetus R51 F1 of the seventeenth day, but the difference in the movements of fetus R36 F1 was much less marked. In kind of movement, however, fetus R49 F1 exceeded fetus R36 F1.

Despite the increase in the strength of the movements, the acquisition of new kinds of movements or individuation of the primitive movements, the nineteenth-day fetus did not execute any complete complex movement; it could not swim; it could not crawl or walk; but it attempted and nearly succeeded in holding a posture of dorsoventral orientation.

The 20th-day fetus.

The twenty-day fetuses were considerably larger and more developed than the nineteen-day fetuses, and the somatic movements of the former were obviously more vigorous than those of the latter. Respiratory movements were observed but they were not rhythmic. Neither did they become rhythmic or automatic after the fetus was removed from the Ringer's solution, although they

were observed. There was, also, extensive development of the tongue movement. The posture attempt or movement showed further development in the 20th day in that it was so often repeated and the rump was rotated in a direction opposite to that of the rotation of the head, to the extent that it was nearly at right angles to the median sagittal plane.

V. IRRITABILITY

Regions of sensitivity

In these experiments, incidentally, some observations were made on the development of tactile sensitivity of the rat fetus. The problem, however, was not thoroughly studied and therefore only some of the outstanding observations are described at this time.

The methods used to arouse the fetus consisted of touching it with the point of a bone probe, a horse-hair bristle, and a human hair, or, in a few cases, a fine rat hair, on the vibrissal region of either side of the snout, the shoulder, the back, the sides, the flanks, the rump, and the abdomen, and in a few instances on the dorsal surface of the forelimbs, the mouth cavity, the forebrain, and the eye.

Light touch with the bone probe--a bone crochet hook sharpened on one end to a fine point--because of its weight was a stronger stimulus than light touch with the horse-hair bristle or the human hair. The horse-hair bristle was one-half inch long and attached to one end of a piece of wood three inches long and one-quarter inch in diameter. The human hair was attached to one end of a bone probe by means of paraffin and the length of the hair from the point of attachment to the free end was four millimeters. The rat hair was taken from the

back of a mother rat and attached to the end of a bone probe by means of paraffin.

The vibrissal region on either side of the snout of the fetus was more or less sensitive to tactile stimulation with the bone probe or the bristle. This was the first region to become sensitive to tactile stimulation, for the responses were elicited by touching this region with the bone probe, or the bristle, in all of the early motile fetuses. With increase in age of the fetus the sensitivity of the vibrissal region increases. This was shown by the readiness with which tactile responses were evoked by touching, with the bristle, the snouts of fetuses representing the early motile stage. Some fetuses, however, responded more frequently and vigorously than others. As indicated by the protocols, the number and strength of the tactile responses exhibited by the youngest and the oldest fetuses of the early motile stage shows roughly that the sensitivity of the fetus increases with an increase in age and development. The difference between the oldest fetuses of the early motile stage and the fetuses of the later stages is even more marked.

Tactile sensitivity of the regions other than the vibrissal region of the snout was not shown by the eighth youngest motile fetuses of the early motile stage. Some of the fetuses whose litter age was 380 hours or more

responded when touched or stroked on the skin over the shoulder, back, sides, and rump with the bristle. (R48 F4, R70 F4, R62 F3, F5, F6, F7, and F9, R58 F3). But these fetuses were not sensitive on the abdomen to tactile stimulation with the bristle. The sensitivity of the shoulder, back, sides, rump and also abdomen to tactile stimulation with the bristle was more evident in the fetuses R61 F3, R69 F1 and F7, and R56 F2 of the dorso-ventral stage. In fetus R56 F2 the sensitivity of the dorsum of the forearm was feeble or doubtful.

Prodding with the bristle in the mouth cavity of fetus R55 F2 evoked response. Prodding with a fine rat hair in the mouth cavity of fetus R52 F2 evoked a vigorous response. This fetus was very easily aroused when it was stroked with the fine rat hair on the back, sides, and rump. In fact it seemed to be easier to elicit a response by stroking with the fine rat hair over the shoulder and back, than on the snout. The litter age of fetus R52 F2 was 405 hours and 12 minutes and the crown-rump length was 16 mm.

Fetus R33 F1 was less sensitive to tactile stimulation with the bristle on the hindlimbs than on the dorsum of the forearm. This fetus was sensitive also on the back, sides, and rump.

Fetus R51 F1, the oldest fetus of the dorso-ventral or extension-flexion stage, whose litter age was 407 hours and whose crown-rump length was 16 to

17 mm., seemed to be sensitive all over to tactile stimulation with the bristle except on the head, in the forebrain region, and on the eye.

Although the data on the development of sensitivity is, as mentioned above, incomplete, it was demonstrated that some of the rat fetuses after the 380-hour litter age were more or less sensitive on the shoulder, back, sides, and rump to tactile stimulation, and that after the 390-hour litter age the abdomen was sensitive and also the dorsum of the forearm.

Finally, near the end of the sixteenth day after insemination the fetuses appear to be sensitive not only on the shoulder, back, sides, rump, abdomen, and dorsum of the forearm, but also on the hindlimbs and in the mouth cavity, which probably means that the tongue or lips are sensitive. Besides, the sensitivity had increased, for some of the fetuses could be aroused by stroking or prodding with a fine rat hair--which was obviously more delicate stimulation than the horse-hair bristle.

The 18-day fetus R36 F1 was sensitive to tactile stimulation with bristle or human hair. When either bristle or hair was stroked across the mouth of the fetus it aroused the fetus to complete or total activity. This fetus was very sensitive to stimulation with bristle or hair on the sides, forelimbs, and hindlimbs. It is,

however, impossible to give any quantitative comparison of the increase of sensitivity of this 18-day fetus over that of the fetuses of the 16th or 17th day. And so it is with the 19-day fetus as well as with the 20-day fetus. In the 20-day fetus the lips were exceedingly sensitive to tactile stimulation.

Tactile responses

Tactile responses or body movements of the motile fetuses nearly always occur when the vibrissal region on either side of the snout or the skin over the shoulder, back, sides, rump, and abdomen, and occasionally of the forelimbs and hindlimbs, are lightly touched with the bone probe, bristle, or hair.

The first tactile response of the rat fetus was lateral flexion of the head and it was elicited by tactile stimulation of the vibrissal region of either side of the snout. The contraction in the youngest fetus was of the side touched or of the opposite side-- that is to say, crossed. In the older fetuses of the early motile stage the contraction which followed tactile stimulation of the snout was nearly always a crossed response, and the immediate movement was lateral flexion of the head, trunk or rump. The contraction, however, was of the trunk, and the head and rump moved passively.

But the immediate movement in response to tactile stimulation of the snout was not always lateral flexion of the head, trunk, or rump, for after the fetus had acquired the movement of simple head extension, or head extension with rotation, then this movement often replaced the more primitive response. This

was verified by all of the motile fetuses of the dorso-ventral stage and of the later stages. Obviously the head extension movement was a withdrawal of the head from the stimulating point.

The immediate movement in response to tactile stimulation of the skin over the shoulder, back, sides, flanks, and rump and abdomen, although not as definite as the movements in response to tactile stimulation of the vibrissal region of the snout of the fetus, generally consisted of lateral flexion of the trunk of the side touched. It was not observed in the six youngest fetuses of the early motile stage, but was recorded for many fetuses whose litter age was 380 hours or more.

Movements other than lateral flexion of the head, trunk, and rump, as the immediate response to tactile stimulation of the skin regions of the shoulder, sides, back, rump, and abdomen were noted for some of the fetuses, and these movements consisted of independent movement of one forelimb, rump ventral flexion, and even head extension. But such responses were the exception rather than the rule.

In fetuses R33 F1 and R51 F1, however, a very light touch with the bristle on the skin over the side or rump evoked feeble contraction of the skin, and skin contraction was recorded also for the two oldest fetuses observed, of 428-hour and 450-hour litter age, respect-

ively. In these same fetuses stronger tactile stimulation of the skin areas other than the vibrissal region of the snout evoked lateral flexion of the head, trunk, and rump of the side touched.

Spontaneous movements

By this term is meant all of the muscular movements exhibited by the rat fetus which were not obviously evoked by exogenous stimuli. They are movements of internal or endogenous origin, that is to say, they originate from within the fetus.

The normal endogenous or "spontaneous movements" of the rat fetus occur while it is in the uterus where it is protected by the amnion, chorion, and liquor amnii. In this environment exogenous tactile stimulation is usually quite impossible, but stimulation by pressure due to the contraction of the uterus, and pressure on it, undoubtedly does occur. With the exception, then, of general pressure without definite localization, all of the movements that are performed or executed by the fetus in its normal environment are of endogenous or spontaneous origin. It is probable in a few instances only that movements which have been recorded as spontaneous movements have been evoked by stimulation due to the manipulations during the experimental procedure to which the fetuses must be subjected,

Spontaneous movements were not observed in the three fetuses R32 F8, F9, and F10. Fetus R24 F1 was the youngest fetus to exhibit spontaneous movement. The litter age of fetus R24 F1 was 378 hours and the crown-rump length was 13.5 mm. This fetus may have

been a little older and slightly more developed than the fetuses R32 F8, F9, and F10, but the difference, if any, was small.

No spontaneous movements were observed for fetuses R24 F5 and F6, even though they were motile fetuses of the same litter as R24 F1. The crown-rump length of these fetuses was 14 mm. The spontaneous movement exhibited by fetus R24 F1 was a feeble movement that consisted of lateral flexion of the head, as was the tactile response exhibited by this fetus.

Some of the fetuses of the early motile stage were very active with spontaneous movements, for example: R27 F1 and F2, R48 F4, R71 F1, R62 F5 and F7, R58 F3; yet other fetuses of the early motile stage were less active spontaneously, for example R70 F1 and F2, R62 F3, R38 F1 and F4. In the dorso-ventral and later stages the difference in amount of spontaneous movement exhibited by viable fetuses of a litter was much less marked. But the older or more developed fetuses exhibited more spontaneous movement than the younger or less developed, as shown by comparison of the spontaneous movements of R50 F5 and R51 F1.

With the exception of the litter R32 the spontaneous movements were exhibited by one or more fetuses of every litter of the early motile stage, and also in the later stages. Not all of the motile fetuses, how-

ever, exhibited spontaneous movements, for fetuses of four litters not mentioned in the protocols of the early motile stage exhibited no spontaneous movements. All of the viable fetuses of the dorso-ventral stage and later stages exhibited spontaneous movements.

Fetus R24 F1, litter age 378 hours, exhibited only one weak lateral flexion movement of the head. Fetus R27 F1, litter age 379 hours, exhibited seven spontaneous movements. Fetus R61 F3, litter age 396 hours, displayed many spontaneous movements. In fetus R51 F1, litter age 407 hours, the spontaneous movements were continuous for many seconds, and finally in the 19-day fetus R49 F1 they were continuous for 25 minutes. The spontaneous movements of the 20-day fetus were vigorous. The ability of the fetus to move spontaneously increased with age and development.

All of the simple movements of the rat fetus were at some time or other exhibited as spontaneous movement. The total reaction of a fetus, whether it was evoked by tactile stimulation or by endogenous stimulation, always consisted of the same kinds of simple movements. But the total reaction was not always exhibited by the early motile or later stages during spontaneous activity.

VI. DISCUSSION

In all forms of animals there exists a definite behavior pattern, which in the adult is more complex than in the embryo or larva. Analysis of the behavior pattern is, therefore, easier to comprehend if its development is studied from the time of its inception or beginning, than if it is studied in the adult. When approached from the developmental point of view it can be correlated by anatomical and physiological studies, and by so doing the anatomical counterpart can be determined.

This has been done by Coghill for *Amblystoma* and Tracy for Toadfish. They have shown that the behavior pattern as it exists in its early stages is simple and becomes, with growth, more and more complex; and furthermore, they have shown that this primitive embryonic behavior pattern is projected into the adult behavior pattern.

Tracy has pointed out that in the various species of fishes the behavior pattern differs. It is common knowledge that the behavior pattern of adult animals differs considerably, and that in man the behavior pattern of individuals differs greatly. Tracy has pointed out some of the physiology concerning the early behavior pattern. He has shown that the fun-

damental behavior pattern in the toadfish is activated by increase as well as decrease of CO₂.

In the mammal, Graham-Brown has shown that progression movements of fetal cats can be activated by "blood stimulus," and that the progression movements are similar to the respiratory movements in this respect.

The behavior pattern of the *Amblystoma* as well as that of the toadfish, which have been described by Coghill and Tracy, consist at first of progression movements and later of posture movements. The components of these early progression movements and posture movements are, obviously, very simple in these forms, for they involve only bilateral musculature which in these forms has a very simple arrangement.

Langworthy ('25) has defined walking as follows: "The act of walking may be considered as composed of two definite factors--one, dynamic, the other, static. The former is made up of alternate orderly flexion and extension of the legs inducing progression; the latter is the postural reaction counteracting the force of gravity and enabling the legs to support the body weight." This definition may satisfactorily comprehend all of the components of walking so far as is necessary for physiological interpretation or analysis,

and if we consider the static factor alone, some information has already been obtained, for Langworthy cites Sherrington's demonstration "that this postural reflex could be accentuated by transection of the brain through the mesencephalon; the antigravity muscles then show a continuous prolonged contraction." So far as the dynamic factor is concerned, no such complete analysis has been made, and apparently Langworthy assumes that the dynamic factor or progression is simply "alternate orderly flexion and extension of the legs." If now, as Langworthy admits, the complicated mechanics of the postural reaction and the tracts involved are not clearly understood, then he should admit also that the mechanics of the dynamic factors are far from being comprehended, for the dynamic factors involve considerably more than "alternate orderly flexion and extension of the legs." It is clear from the above that the essential requirements for understanding and explaining progression and posture demand a complete description of the development of the behavior pattern--since this includes progression and posture--as well as a description of the anatomical counterpart of the behavior pattern.

This has been done to a certain extent at least in these experiments on development of movement in the rat fetus, for although the description is not

complete up to walking, yet the primitive behavior pattern has been described in terms of simple movements. The components of progression as shown by the early motile rat fetus consist of alternate lateral flexion of the trunk, forelimb backward and forward movements, flexion and extension of the forearm, hindlimb abduction and adduction; and the muscle masses as indicated by these movements are a bilateral group in the trunk at the level of the shoulder, proximal masses in the forelimbs, and proximal masses in the hindlimbs. So far as the physiology is concerned, the trunk movements dominate the forelimb movements, and the hindlimb movements are dominated by the movements of the rump. There may be definite rhythms of the forelimb movements, and even of the hindlimb movements, but these--if they do exist--because of the fact that they are influenced or dominated by the trunk rhythm, are submerged. That the mechanism of this early behavior pattern is activated by "blood stimulus," or, as Tracy has shown, by increase or decrease in CO₂, is shown by the experiment recorded in the Protocols for fetus R48 F6, in which clamping the umbilical cord with the tissue forceps even at this early stage of development, quickly or in a few seconds evoked movements of the fetus which in their analysis were identical with progression movements, in so far as they were developed at this time. Furthermore, clamping the um-

bilical artery alone required longer time to evoke movements than clamping the umbilical veins. This indicates that the source of the metabolites, or CO_2 , emanated from the tissue cells of this embryo or fetus, and not from the placenta or from the mother. The activation, then, of the mechanism of movement in the rat fetus even in the early motile stage is primarily of endogenous origin. Experimentally, however, increased activation of the motor mechanism occurs when the fetus is stimulated on the snout with the bristle; and such stimulation, if it occurs when the motor mechanism is at the height of activation, increases or raises the irritability of the whole mechanism until the total reaction may result. Obviously tactile stimulation is not the usual or normal method of activation of the fetus in utero, but when the movements of the fetus occur in utero, they are of endogenous origin. Although the earliest movements exhibited by the youngest rat fetus studied, or R32 F8, were evoked by tactile stimulation of the snout, this does not necessarily prove that the first movements of a rat fetus are of exogenous origin.

Langworthy, Weed ('17), and Graham-Brown have shown that pouch-young opossums, very young kittens, and fetal cats when decerebrated, that is to say, when the brain is transected at the level of the mesencephalon, show no decerebrate rigidity; but, on the other hand,

these young animals and fetuses exhibit progression movements. Decerebrate rigidity occurs, however, in the older opossums and older kittens. The phenomenon of decerebrate rigidity was demonstrated by Sherrington in 1896, and he has shown that the musculature involved consisted of the antigravity muscles. Langworthy further states that the static factor of walking is primarily posture and the dynamic factor of walking consists of flexion and extension of the forelimbs and hindlimbs. Interesting and significant as these observations are, and though they suggest the components of walking, no complete anatomical or physiological analysis has been, on this basis, accomplished. The fact that progression movements occur in very young opossums, fetal cats, and kittens, instead of decerebrate rigidity, is explainable upon the basis of the observations which the writer has made on fetal rats. It seems to be generally conceded that the oldest mechanisms are the last mechanisms to disappear in dying animals. The writer has found that the progression movements in fetal rats antedate the posture movements. On this basis, then, the progression movements exhibited by the decerebrate cats of Graham-Brown, the pouch-young opossums of Langworthy, and the young kittens of Weed, were movements of dying animals. According to the results of these observers one would infer that their animals were in-

capable of posture movements even before they were decerebrated. The writer ventures to question whether Graham-Brown's fetal cats, Weed's kittens, and Langworthy's opossums may not have exhibited posture movements. The observers may have failed to recognize posture movements because of an assumption that decerebrate rigidity constitutes the static factor of posture.

Upon the basis of his study of fetal rats the writer cannot accept decerebrate rigidity of the Sherrington experiment as adequately representing the normal mechanism of posture. He believes that the investigators who have followed this experimentation have failed to recognize the primitive components of posture. For the writer has shown that progression movements which were exhibited in the early motile stage preceded or antedated posture movements which did not appear until the dorsoventral stage. The component of the posture attempt consisted of maintained contraction of the trunk muscles, maintained backward movement of the forelimb of the contracted side, and maintained head extension. Both progression movements and posture movements were activated by endogenous stimuli. With increase in age, that is to say, with growth, the development of progression as well as posture proceeds; but the primitive pattern

persisted throughout, even up to the 20-day fetus, though differing somewhat in strength, duration, and kinds of movements. The fact that both progression and posture can be traced from their earliest inception in the albino rat fetus and can be analysed into their constituent simple movements suggests that this approach to the ultimate analysis of progression and posture is basic to the physiological method of analysis that has been generally employed in the study of posture.

VII. SUMMARY

The earliest movement consisted of lateral flexion of the head. It was caused by a contraction of muscle masses in the trunk at the level of the shoulder. Although the movement as it occurred was of only one side, it is probable that the movement was bilateral, but not necessarily alternate in sequence. Movement in the rat fetus develops in an orderly manner. Development is undoubtedly cephalocaudad in the trunk, for the extent of the flexion was more pronounced in the more developed fetuses of the early motile stage than it was in the youngest fetuses of this stage. Development of movement in the forelimbs and hindlimbs unquestionably was proximodistal, for movements of the wrist, or paw, and foot did not occur before flexion and extension movements of the forearm, and movements of the toes were not observed in fetuses even of the 20th day. The movement of the trunk at the time of its earliest beginning was bilateral and became, later, alternate in sequence. In the dorso-ventral extension flexion stage the movement of the head, as well as of the rump, was dorso-ventral. Aside from the fact that movement develops according to the plan described above, development of qualities of movements were also demonstrated. For in the older fetuses of the dorso-ventral stage the

quality of maintained contraction was observed in the lateral flexion of the trunk, backward extension of the forelimb, and head extension. In the early motile stage the extent of development of movement consisted of lateral flexions of the trunk, forelimb movements forward and backward, flexion and extension of the forearm, and hindlimb abduction and adduction. The forelimb movements exceeded in extent of development those of the hindlimbs. The trunk movements dominated the forelimb movements and the hindlimb movements were closely allied with, or even dominated by, the movements of the rump. These movements described above are progression movements, and constitute the first complex movement.

At the end of the 16th day the second complex movement--the posture attempt--was decidedly evident, although not completely developed. The trend of development, therefore, in complex movement was: first, progression, then, posture. With the appearance of mouth opening and tongue movements in the dorso-ventral stage, or after the 393rd hour of gestation, the beginning of two complex movements--respiration and swallowing--was indicated. The exact time of appearance of these movements, however, in the rat fetus has not yet been determined, although they appear in the dorso-ventral stage. Indications of respiration movements, other than mouth opening and tongue movements,

were noted in the fetus of the 18th day and of the 19th day, for thoracic constrictions were observed. These, however, were not rhythmic, neither were they automatic. Even in fetuses of the 20th day, although gasping movements occurred, they were neither rhythmic nor automatic. This does not mean to say, however, that automatic respiration or respiratory movements do not exist at this age. The data on this point, so far, is insufficient to warrant a conclusion.

The component movements of the behavior pattern have been determined for the albino rat fetus from the time of the first appearance to the beginning of the 17th day of gestation. On the basis of kinds of simple movements exhibited by the albino rat fetus, three definite stages of development have been recognized during the sixteenth day of gestation. The writer is aware that development of movement, like growth, is a continuous process. Nevertheless, the recognition of these three stages has the advantage that it facilitates description and study of the behavior pattern of the albino rat fetus.

The stages recognized are:

1. The non-motile stage which includes all viable rat fetuses that exhibited no movement and were incapable of movement. This stage correlated with age of the fetus appears to end at or near

the 378th hour of gestation.

2. The early motile stage which includes all the motile fetuses that exhibited either the first movement--lateral flexion of the head--or all of the simple movements of the primitive behavior pattern, which consisted of the following simple movements:

- a. Lateral flexion of the head, trunk, and rump.
- b. Alternate lateral flexion of the trunk, head and rump.
- c. Forelimb backward and forward movement.
- d. Flexion and extension of the forearm.
- e. Hindlimb abduction and adduction.

This stage, correlated with age of the fetus, appears to begin at or near the 378th hour of gestation and ends at or near the 390th hour.

3. The dorso-ventral extension-flexion stage, which includes all motile fetuses that exhibited the movement of head extension and also the movements listed for the early motile stage.

This stage, correlated with the age of the fetus, appears to begin at or near the 390th hour of gestation and arbitrarily ends at the 408th hour.

The observations which have been made on fetuses of the later stages, although they are incomplete, verify

*Complete ages
from 378th
to 408th*

those recorded for the fetuses of early stages. The later stages can be profitably studied and analysed with the aid of motion pictures.

The vibrissal region of the snout of the rat fetus was the first region to become sensitive to tactile stimulation, for fetuses of the 378th hour of gestation responded when touched lightly with the bone probe or horse hair bristle.

Sensitivity to tactile stimulation of regions other than the snout was evident in the older fetuses but not in the younger fetuses of the early motile stage.

The sensitivity of the fetus to tactile stimulation increases with age and development. The exact order of development of tactile sensitivity in the different regions has not been determined.

The constant reflex responses evoked by tactile stimulation were:

1. Crossed lateral flexion of the head or trunk when one side of the vibrissal region of the snout was touched, which occurred in all of the fetuses of the early motile stage and occasionally in the dorso-ventral stage.
2. Head extension, with or without rotation, which occurred when the vibrissal region of one side of the snout was stimulated, and which was a movement away from the point of stimulus.

3. Lateral flexion of the trunk, which occurred when the shoulder, side, or back of the fetus was stroked lightly with the bristle or hair, and which was a contraction of the side touched. This reflex was observed even in the older fetuses of the early motile stage.
4. Skin contraction which occurred when the skin over the rump of the fetus was lightly touched with the bristle and was first observed in fetuses of the dorso-ventral stage.
5. The tongue and mouth movements were not as constant as the above reflexes, though they could be evoked by tactile stimulation of the mouth cavity or the snout.

Despite the fact that the first movements of the rat fetus as observed were tactile responses, and notwithstanding the early appearance and establishment of spontaneous movements, the data at this time is insufficient to permit of a definite statement as to whether endogenous or exogenous activation is the first to appear.

Endogenous stimuli activate the progression mechanism as well as the posture mechanism in a manner similar to the activation of the respiratory mechanism in the adult, and that this activation is by "blood stimuli" or increase and decrease in CO_2 has been shown.

The irritability of the rat fetus is dependent

on the degree of activation of the motor mechanism by endogenous stimuli and increase of the irritability occurs when exogenous stimulation is applied.

The results of this work suggest that an analysis of movement of the fetus is basic to the problem of progression and posture.

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