FACTORS INVOLVED IN THE EJECTION OF MILK*

FORDYCE ELY
Kentucky Agricultural Experiment Station
AND
W. E. PETERSEN
Minnesota Agricultural Experiment Station

Cows which habitually "let down" or "hold up" their milk are common in all herds. Several theories have been advanced in an effort to explain the physiological processes involved, but each has been found at fault in some regard. In reviewing the literature dealing with the factors involved in the ejection of milk we find that the majority of investigators have failed to differentiate between the processes involved in the synthesis or the secretion of milk within the gland, and the act of ejecting the milk from the alveoli and the small ductules. This has caused some confusion in the interpretation of experimental results.

LITERATURE REVIEW

Routh (21) and Ribbert (20) offered evidence at an early date that the nervous system does not exercise a direct control over the combined acts of secretion and ejection. McKenzie (16) and McCandlish (15) injected numerous drugs, several of which might be classed as nerve stimulants, and failed to produce a marked effect on the rate of secretion or ejection of milk. Both, however, noted that pituitrin produced a marked galactagogic effect.

McKenzie (16), working with cats, noted some galactagogic effect from injecting extracts of corpus luteum and pineal body, and report some inhibitory effects of placental extracts on milk secretion. In these reports, however, no differentiation was noted between "secretion" and "ejection." Cannon and Bright (1) concluded that the autonomic nervous system was essential to lactation, from their work with a sympathectomized dog. They describe the effect as a belated one which caused the mother to be indifferent to her young and the gathering of a viscous, creamy material in the glands.

Hammond (7) and Macy *et al.* (13) accept Gaines (3) view that milk secretion in the sense of formation of the milk constituents is one thing and the ejection of the milk from the gland after it is formed is quite another.

Ingelbrecht (11), working with ten lactating rats, sectioned their spinal cords between the last thoracic and first lumbar vertebrae, thus incapacitating the six posterior glands and permitting the anterior six to remain intact. Nursing young died when permitted access only to the posterior six glands,

Received for publication October 28, 1940.

* The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

but when two of the anterior glands were offered, all glands functioned normally, due probably to a stimulus which was transmitted in some manner to the denervated glands. Selye *et al.* (24) also found that nursing caused continued gland function in adjacent glands which were not nursed.

Gaines and Sanmann (4) Petersen, Palmer and Eckles (19), and Swett *et al.* (28) have recovered as much as 100 per cent of the milk from excised glands which they would have expected to obtain from a normal milking of the same glands. Their investigations have also demonstrated the existence of residual milk, or milk which cannot be removed from the glands under normal milking conditions.

Zietzschmann (32) takes the view that the involuntary excitation of the muscles of the teat provokes the retaining of milk in the gland, while most investigators are of the opinion that there is ample argument for the opposite view in nursing Cetacea where the act of suckling is incompatible with the under-water life of these animals. The ducts of their mammary glands are enlarged into reservoirs from which the milk is ejected into the mouths of the young. Circumstantial evidence has gradually accumulated which indicates the presence of a somewhat similar musculature within the bovine mammary gland, these muscles surrounding the small ducts and alveoli, and that the act of milk ejection consists in the contraction of these muscles. Gaines (3) found that the ejection of milk in a goat was coincident with a high intra-gland pressure and that low-pressure latent periods occurred between high-pressure periods. This pressure as related to the rate of milk ejection was further demonstrated by Tgetgel (29) who explains the sudden swelling of the glands from an internal pressure, as the milk is ejected before being withdrawn. Hammond (7), after reviewing the literature, offers an entirely different explanation for the occurrence of this pressure. He believes, "It is due to erection in the udder and nipples, which is caused reflexly by stimulation of the nipple by the act of sucking or milking."

Gieling and Robbins (5) point out that the preparations of the anterior lobe of the pituitary body exert their characteristic effects slowly, require repeated administration and affect more particularly the structural elements of the body; for example, the growth of the mammary gland, the persistence of secretion and other time-consuming functions. The posterior lobe, however, is much more abundantly supplied with nerves and its extracts "Elicit an immediate pharmacodynamic response" on isolated tissue preparations (*e.g.* the uterus) or in the intact animal.

Oliver and Schafer (17) noted the sudden increase in blood pressure following intravenous injection of extracts of the posterior lobe. Ott and Scott (18), Gaines (3), McKenzie (16), Schafer (22), Hammond (6), Hill and Simpson (9 and 10), Simpson and Hill (25 and 26), Turner and Slaughter (31), Maxwell and Rothera (14) injected pituitrin intravenously using various species including the human. They agree to a stimulating effect although all except Gaines fail to differentiate between secretion and ejection. Two of these (3) and (25) report a lessening in effect when the administrations were continued for a period of time. Several (6 and 25) are of the opinion, however, that the response to pituitrin injection is caused by a direct action of the principle on the secreting tissues of the gland, and that it is not due to the contraction of smooth musculature around the secreting cells, a precedent for which has been mentioned with suckling Cetacea. Turner and Slaughter (31) are "Inclined to the theory that pituitrin is not a galactagogue but rather acts on the mechanism normally effective during the milking process. We are inclined to believe that contractile elements in the walls of the alveoli and ducts furnish the *vis a tergo* observed."

Kamn *et al.* (12) accomplished a fairly complete separation of the oxytocic and the pressor principle from pituitrin. The name "Pitocin" was chosen to designate a solution containing the oxytocic principle, alpha-hypophamine, which is "comparatively free" from pressor activity. This product is otherwise referred to as oxytocin or obstetrical pituitrin because its action is specific for smooth muscle and it is used by the medical profession to stimulate uterine contractions. Kamn's "Pitressin" designates a solution of the pressor principle, beta-hypophamine, which is "comparatively free" from the oxytocic principle and this "surgical pituitrin" is frequently used to reduce surgical shock. Stehle (27) has more recently devised other methods for effecting a separation of these two principles. It is quite possible that the existence of these two fractions in pituitrin may account for the differences in the observed effects on the mammary gland when injected intravenously.

EXPERIMENTAL

According to Turner (30) and Espe (2) each half of the bovine mammary gland derives its nerve supply from three sources: (1) the ilio-hypogastric nerve, (2) the ilio-inguinal nerve and, (3) the posterior inguinal nerve. The first carries only afferent fibers from the gland periphery while the second and third carry both afferent and efferent fibers between the interior of the gland and central nervous systems. It was believed, therefore, that if an operation could impair the functioning of (2) and (3) nerve supplies to half the udder, practically all motor or efferent impulses would be removed and the intact half of the udder could be used as a check.

Three Jersey cows were selected from the Kentucky Agricultural Experiment Station herd on which to experiment, to determine more exactly the relationship which exists between the nervous mechanism and the ejection of milk. The first two cows, E 124 and E 237, were chosen because they were due to freshen January 2nd and 4th, respectively, and it was possible to treat them together experimentally. On November 17th, 1936, while both cows were dry, the left half of the udder of each was denervated to the extent of removing about two inches of the sympathetic trunk nerve, which is made up of the ilio-inguinal and the posterior inguinal nerves, at a point just below the left inguinal ring. Each cow received as a general anesthetic, one ounce of chloral hydrate and, after being placed on the operating table, 1 per cent procaine was used as a local anesthetic. The incision was made at a point above the secreting tissue about midway between the left front and rear teats. This nerve trunk is located between the external pudic artery and vein which descend together through the left inguinal ring. No infection occurred in either case and within eight or ten days the wounds were well healed. These cows freshened normally early in January, 1937, and were subjected to experimental milkings which were designed to measure the effect of the denervation on the rate of ejection of milk from the glands. A mechanical milker* was especially designed which directed the milk from each half of the udder into a separate container, and which hung on a Chatillon milk balance suspended on opposite sides of the cow. Thus both halves of the udder of each cow were subjected to a uniform vacuum at the same time and the yield of milk was observed and recorded at fifteen-second intervals.

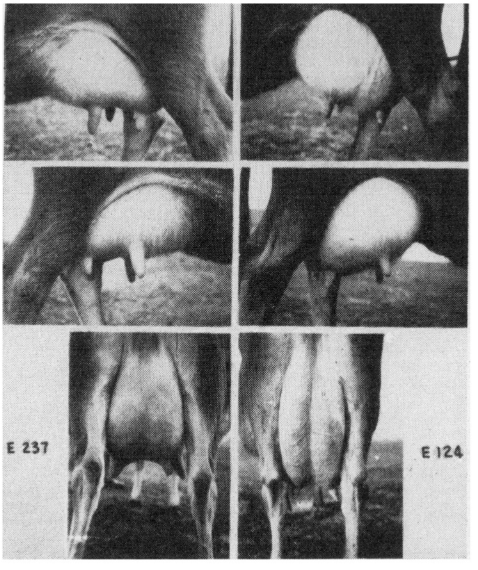
In September, 1938, another cow, E 307, was operated on in exactly the same manner. She calved normally on October 20th and for a period of three and one half months was experimentally milked using the same special equipment.

RESULTS

The photograph shows views of the udders of the first two cows, E 124 and E 237, taken soon after they freshened. The development of the left half of these udders seems not to be affected by the denervating operation. Figures 1 and 2 show the rate of ejection of milk (6 A. M. and 5 P. M.) each line representing an average of 13 milkings. In each figure the solid line represents the right or intact half of the udder while the broken line shows the response from the left or denervated half. It is quite apparent that the denervated half of the gland seemed as able to eject the milk as the intact half. Figure 3 shows the response measured in exactly the same manner for the third cow, E 307, and each line represents an average of twenty-eight normal milkings. No significance is given to the fact that in each individual milking the left half of 307's udder yielded more than the right or intact half. Such a difference was not noted in the other cows and is probably an individual characteristic of the normal udder of the experimental subject. These data indicate that the motor or efferent nerve supply to the bovine udder has little to do with determining the rate of ejection of milk under normal conditions. E 307 was then subjected to a series of experiments to determine the effect of the efferent nerve supply to the glands under various abnormal conditions such as fright and intravenous hormone injections.

* Courtesy of Mr. L. Dinesen, Perfection Milker Corp.

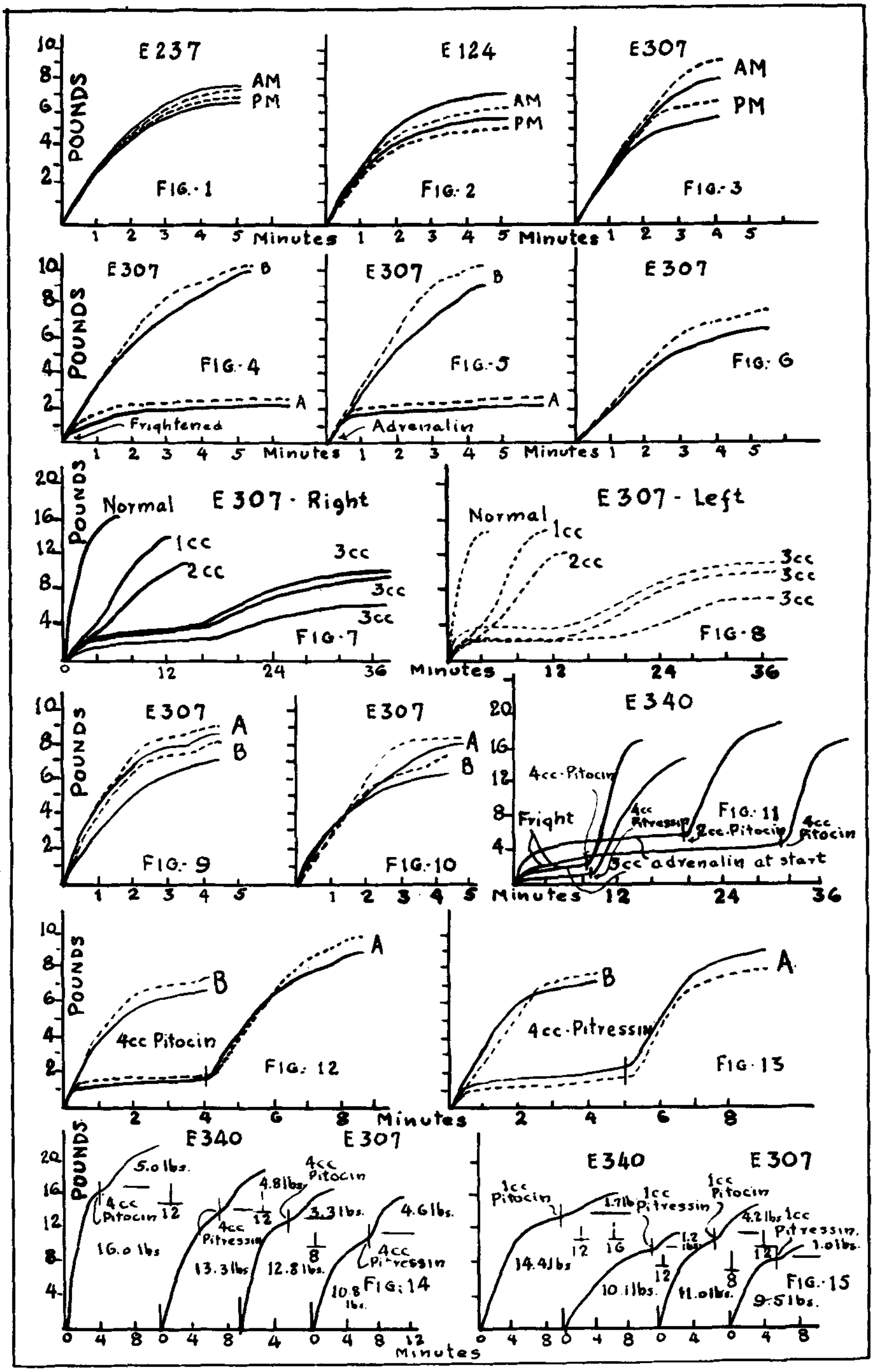
The effect of fright on the ejection of milk: Physiologists agree that animals can exist in an apparently normal state following gross sympathectomy but are unable to adapt themselves to a changing environment. It was thought that there might be a difference in the response of the two halves of the udder as measured by the rate of ejection of milk if the cow was severely frightened. Accordingly, E 307 was systematically frightened as the mechanical milker was attached. Frightening at first consisted in placing a cat on the cow's back and exploding paper bags every ten seconds for two minutes. Later the cat was dispensed with as unnecessary.



Photograph shows three views of the udders of E 237 and E 124 taken soon after freshening.

The result is shown in figure 4. Both halves of the udder responded alike in A. The milk was promptly drained from the cistern, followed by practically a complete cessation of ejection. In this instance 11.0 pounds of milk was removed from the entire udder by hand milking thirty minutes later, although the gland was still relatively hard, but considerably more relaxed than at the time of frightening. The subsequent milking yielded 19.8 pounds, or 3 to 5 pounds above normal. Figure 4 is typical of similar responses in repeated experiments. These experiments with fright indicate that the effect of denervation is not reflected by a different response as measured by the rate of ejection of milk.

The effect of intravenous adrenalin injections on the rate of ejection of milk: Physiologists agree that adrenalin is ejected into the blood from the medulla of the suprarenals in especially large quantities at a time of emo-



E 237
AM
PM
POUNDS
FIG. 1
Minutes
E 124
AM
PM
FIG. 2
Minutes
E307
AM
PM
FIG. 3
E307
B
A
Frightened
FIG. 4
Minutes
E307
B
A
Adrenalin
FIG. 5
Minutes
E307
FIG. 6
E 307 - Right
Normal
1cc
2cc
3cc
3cc
3cc
FIG. 7
E 307 - Left
Normal
1cc
2cc
3cc
3cc
3cc
FIG. 8
Minutes
E307
A
B
FIG. 9
E307
A
B
FIG. 10
E340
4cc Pitocin
Fright
4cc Pitressin
2cc Pitocin
4cc Pitocin
3cc adrenalin at start
FIG. 11
Minutes
B
A
4cc Pitocin
FIG. 12
B
A
4cc Pitressin
FIG. 13
Minutes
E340
E307
5.0 lbs.
4cc Pitocin
16.0 lbs
4.8 lbs
4cc Pitressin
13.3 lbs
4cc Pitocin
3.3 lbs.
12.8 lbs.
4.6 lbs.
4cc Pitressin
10.8 lbs.
FIG. 14
E340
E307
1cc Pitocin
1.7 lb
14.4 lbs
1cc Pitressin
10.1 lbs.
1cc Pitocin
1.2 lbs
11.0 lbs.
4.2 lbs
1cc Pitressin
1.0 lbs.
9.5 lbs.
FIG. 15
Minutes

tional stress. It is also believed that musculature served by sympathetic nerves shows an especial response to the action of adrenalin. The sympathetics had been removed from the left half of the udder of E 307, and so it was decided to substitute for the fright an injection of 4 cc. of adrenalin solution (1 to 1000 Parke, Davis and Company) and note the result on the rate of milk ejection. This was repeated a number of times and a typical result is shown in figure 5 in A. The similarity to A in figure 4 is apparent. An hour after this particular milking 7.3 pounds of milk were removed by hand after considerable effort. The subsequent milking B was 19.1 pounds and above normal as was the case following fright.

In order to be assured that the response was due to the effect of the intravenous injection of adrenalin and not due to a degree of fright occasioned by the act of consummating an intrajugular injection, the experiment was repeated using 4 cc. of physiological saline instead of the adrenalin solution. Figure 6 shows that the saline failed to cause the response which was typical of adrenalin or fright. Undoubtedly some pain and excitement is caused by the act of making the injection, but sight and sound stimuli (exploding bags, etc.) seem to have a much more pronounced effect as measured by the rate of milk ejection.

Four cubic centimeters of the adrenalin solution seemed to be a serious shock to this cow, E 307. She always took her feed readily when it was placed before her prior to milking. Following adrenalin injections, she stood still, trembled slightly and refused to touch her feed and her udder became hard. Later experiments revealed that 4 cc. doses seemed to have a still more marked effect. In one instance E 307 threw herself three times in the stanchion, and due to such violent struggles, it was impossible to keep the milker attached. It was, therefore, considered advisable to limit the adrenalin injections to a maximum of 3 cc. to cows of her size (1000 lbs.).

The effect of intravenous injections of different quantities of adrenalin on the rate of ejection of milk: It was thought advisable to determine the effect of quantitative intrajugular injections of the adrenalin solution. E 307 was again used as the experimental subject because at the same time it would be possible to again measure the effect of denervation on the rate of response. Two to four days were allowed to lapse between experimental injections in order to permit the cow to resume her normal milking rate.

Figures 7 and 8 indicate that as the amount of adrenalin solution injected intravenously at the beginning of milking is increased, more time is required for its effect to diminish and permit the milk to be ejected. Figure 7 shows the response in the right or intact half of the udder, and figure 8 shows the same milkings for the left half of the udder which had been denervated. The similarity is quite apparent. Sixteen to twenty minutes elapsed before a relatively small amount of milk was ejected at a slow rate following the injection of 3 cc. of the adrenalin solution. The responses were less marked when smaller amounts of adrenalin were injected. In each instance as the amount injected was reduced the response in terms of rate of ejection of milk more closely approached normal. Very similar results were noted when the series of injections was repeated on the Jersey cow E 194, a large-uddered fresh cow of known quiet disposition.

The effect of intravenous injections of posterior pituitary lobe fractions on the rate of ejection of milk: Due to the fact that pharmacodynamic responses, attributed to intravenous injections of posterior lobe fractions, were as pronounced in their effects as with similar adrenalin injections, it was decided to measure their effect on the rate of ejection of milk. Data were obtained in exactly the same manner as described for the adrenalin injections. E 307 was again used as an experimental subject. Repeated experiments with other cows also gave similar results.

Figure 9 shows the effect of an intravenous injection of 4 cc. of Pitocin (oxytocin 1 : 100) at the start of milking. The relationship between milking A, experimental, and B, the subsequent milking, is very typical of the many times this experiment was repeated. Again both halves of the udder responded in the same manner and the total yield following injection was from 2 to 5 pounds above normal, and the subsequent milking B was correspondingly less. Figure 10 shows the effect of an intrajugular injection of the same amount (4 cc.) of Pitressin (pressor fraction 1 : 100). The response in this case was the same as with Pitocin. The fact must be borne in mind, however, that Kamm *et al.* (12) do not claim that these two active fractions of pituitrin are completely separated in the Pitocin and Pitressin. There probably exists as much as twenty per cent Pitocin in the Pitressin and vice versa. When 4 cc. of either Pitocin or Pitressin was intravenously injected at the start of milking the result was a more complete drainage of the gland. This result seems directly opposed to the effect of fright or adrenalin solution when injected in a like manner.

It was decided, therefore, to determine the effect of delayed injections of posterior lobe fractions, following fright or adrenalin injections, at the start of the milking act. The results, using Jersey cows E 340 and E 307, are shown in figures 11, 12 and 13. These figures indicate that following fright, cessation of ejection is typical, but that within 30 seconds after the intrajugular injection of 4 cc. of either Pitocin or Pitressin, the ejection of milk is resumed in a very positive manner, and resulted in each instance in a total milk yield which was above normal, A. The subsequent milking B was always below normal in amount.

Jersey cow E 340 was used in a series of similar experiments, figure 11. These and experiments with other cows produced similar results when measured in terms of the rate of ejection of milk. There exists every indication that when 4 cc. of either of the posterior pituitary lobe fractions is intravenously injected, the result will be a prompt resumption of rapid milk ejection. The length of time which is permitted to pass following the initial frightening or adrenalin injections seems not to affect the response to the delayed injections of the posterior lobe fractions.

When smaller quantities of Pitocin and Pitressin were used, following a standard intrajugular injection of 3 cc. adrenalin solution, the response was much more pronounced using Pitocin than Pitressin. Such data would seem to indicate that the response in the case of Pitressin, as measured by the rate of ejection of milk, might be due to the presence of Pitocin contained therein.

The effect of intravenous injections of Pitocin and Pitressin after a normal complete milking: Following a normal milking of two Jersey cows, E 340 and E 307, 4 cc. of Pitocin was injected intravenously and 4 days later the experiment was repeated, using Pitressin in place of Pitocin. The results are shown in figures 14 and 15.

A very marked response to 4 cc. of each of the posterior lobe fractions was noted. The yield of milk was slightly in excess of the expected normal yield. When the experiment was repeated using only 1 cc. of each fraction a greater response was noted in favor of the Pitocin. Apparently these "Super Strippings" consisted of milk which was literally squeezed from the alveoli and small ductules due to the presence in the blood of the oxytocic fraction of the product of the posterior lobe of the pituitary. The responses shown in figures 14 and 15 are typical of those obtained in other experiments using other cows.

The composition of the "Super Strippings" as compared with the normal complete milking is of interest. The following table shows only slight differences in specific gravity (lact. corrected to 60° F.), protein ($N \times 6.38$) and lactose, when compared on a fat free basis. Great differences were apparent, however, in the per cent of fat.

	Cow E 332		Cow E 307	
	Normal	Pitocin Super Strippings	Normal	Pitocin Super Strippings
Milk lbs.	10.9	3.2	8.8	3.6
Specific Gravity	1.0338	1.0207	1.0347	1.0215
Lactose %	4.95	4.44	5.83	4.08
Protein %	4.52	3.87	4.17	3.75
Fat %	3.8	17.0	4.0	17.0

The percentage of fat in the "Pitocin super strippings" seemed to reflect the completeness of the normal milking. One cow, E 340, was subjected to this experiment on numerous occasions. Often she became excited and failed to let down her milk normally. Consequently her "normal" milking on one occasion amounted to only 7.6 pounds and tested as low as 1.9 per cent fat, while her super strippings which followed the injection of 2 cc. of Pitocin were equal in amount and contained 10 per cent fat.

On other occasions other Jersey cows were milked normally followed by two minutes of hand stripping preceding the intravenous injection of 2 cc. of Pitocin. Super strippings so obtained usually ranged from 14 to 24 per cent fat and the subsequent milking was always proportionately lower in fat.

A SUGGESTED THEORY BASED ON THESE FINDINGS

The delicate balance between the product of the suprarenal medulla, adrenalin, and the oxytocic principle of the posterior lobe of the pituitary body, in the blood of the cow at the time of the milking act, seems to be responsible for the rate of ejection of milk. The resection of the sympathetic nerves to the gland seem to play no important part as is shown in these experiments. The palpation of the teat, which so quickly increases intra-glandular pressure, can cause an impulse to reach the central nervous system through the afferent or sensory fibers of the ilio-hypogastric nerve which remained intact in these experiments. This teat palpation, however, is only one source of sensory impulses which reach the central nervous system, and this seems to be the initial step in a series of events which result in a high intra-glandular pressure.

There are many other sources of afferent stimuli which presumably might cause similar effects which occur regularly in a well-managed dairy. Rattling milk buckets, washing udders, the placing of feed before the cows, muzzling calves, etc., all occur regularly and are associated with the milking act or the relieving of the pressure within the gland. Any one or all of these, conceivably can cause afferent impulses to reach the central nervous system which, in turn, stimulates the posterior lobe to secrete the oxytocin into the blood, and it is this which is believed to be largely responsible for the increase in intra-glandular pressure, which literally squeezes the milk from the alveoli and smaller ductules. On the other hand, a variety of afferent impulses may reach the central nervous system of quite a different sort. Fright, caused by any unusual event, could in a similar manner, reflexly stimulate the natural production of adrenalin by the medulla of the suprarenals. Thus, under the influence of emotional stress, an extra quantity of adrenalin is ejected into the blood.

Evidence as to the very existence of the musculature surrounding the alveoli and small ductules is only circumstantial, but nevertheless quite convincing. The same may be said for the existence of a larger quantity of oxytocin in the blood at the moment the gland reaches its high point in pressure. These constitute special problem assignments which would throw still more light on this problem.

It would seem, therefore, that the positive act of "letting down" milk may be best explained as a conditioned reflex, and directly due to a high intra-glandular pressure caused by the presence of active oxytocin in the blood, which is responsible for the contraction of the alveoli and small ductule musculature. On the other hand, the failure to "let down" milk is similarly due to the presence of adrenalin in the blood, which prevents the muscular contractions which are responsible for the high intra-glandular pressure.

SUMMARY AND CONCLUSIONS

Data are presented describing a series of experiments using Jersey cows, subjecting them to fright stimuli and intrajugular injections of adrenalin (In sol. 1:1000), Pitocin (oxytocic principle of the posterior pituitary lobe 1:100) and Pitressin (pressor principle of the posterior pituitary lobe 1:100). The left half of the udder of three of these cows had been denervated, and the response of this half of the gland was compared with the right or intact half measured in terms of the rate of ejection of milk. These data seem to justify the following conclusions.

1. Denervating the gland during the dry period resulted in no effect on the rate of ejection of milk during a subsequent lactation. There was also no change in the appearance of the two halves of the udders following the operation. This is additional evidence that the act of milk ejection is not under the direct control of the central nervous system.

2. Fright and intrajugular injections of adrenalin resulted in cessation of ejection of milk. The amount of adrenalin injected seems to determine the length of time that must elapse before natural ejection is possible. Presumably this length of time would also be proportional to the degree of fright, but this is difficult to measure.

3. Other symptoms of adrenalin shock were: a hard udder, refusal of feed, trembling and other signs of a severe nervous shock.

4. Intravenous injections of 4 cc. of either Pitocin or Pitressin caused the gland to be more completely drained than would be the case with a normal complete milking. This was also the case when the injection of these posterior pituitary lobe fractions followed fright or adrenalin injections, or at the end of a normal complete milking.

5. A smaller quantity of Pitocin showed greater potency in inducing prompt resumption of rapid ejection than was the case with Pitressin. These data support the belief that the effect of Pitressin may be due to incomplete separation of these two pituitrin fractions.

6. The extra or residual milk removed from the udder, following the injection of Pitocin, varied from normal composition of milk chiefly in per cent of fat. As one would expect, the more complete the normal milking the higher the per cent of fat in the "super strippings." The per cent of fat in these strippings ranged from 7.6 per cent to 24.0 per cent in a series of experiments.

7. A new theory is advanced which explains the "holding up" and "letting down" of milk, based on the results of these experiments.

REFERENCES

(1) Cannon, W. B. and Bright, E. M. A belated effect of sympathectomy on lactation. Am. J. Physiol., **97**: 319–321. 1931.

(2) Espe, D. L. Secretion of milk. Collegiate Press Inc., Ames, Iowa, pp. 29–40 and Chapter VI, pp. 115–154. 1938.

(3) Gaines, W. L. A contribution to the physiology of lactation. Am. J. Physiol., **38**: No. 2, 285–312. 1915.

(4) Gaines, W. L. and Sanmann, F. P. The quantity of milk present in the udder of the cow at milking time. Am. J. Physiol., **80**: 691–701. 1927.

(5) Gieling, E. M. D. and Robbins, L. I. The posterior lobe of the pituitary gland of the whale; and pituitrin and its fractions pitressin and pitocin. The pituitary gland, p. 437. Williams and Wilkins, Baltimore. 1938.

(6) Hammond, J. The effect of pituitary extract on the secretion of milk. Quart. J. Exp. Physiol., **6**: No. 4, 311–338. 1913.

(7) Hammond, J. The physiology of milk and butterfat secretion. Vet. Record N–S, **16**: 519–535. 1936.

(8) Hammond, J. and Hawk, J. C. Studies in milk secretion. II. The relation of the glands of internal secretion to milk production. J. Agr. Sci., **8**: No. 2, 147–153. 1917.

(9) Hill, R. L. and Simpson, S. The effect of pituitary extract on the secretion of milk in the cow. Proc. Soc. Exp. Biol. Med., **11**: 82–85. 1914.

(10) Hill, R. L. and Simpson. S. The effect of pituitary extract on milk secretion in the goat. Quart. J. Exp. Physiol., **8**: 103–111. 1914.

(11) Ingelbrecht, P. L'influence du systeme nerveux central sur la mamelle lactante chez le rat blanc. Compt. Rend. Soc. de Biol. **120**: 1369–1371. 1935.

(12) Kamn, O., Aldrich, T. B., Grote, I. W., Rowe, L. W. and Bugbee, E. P. The active principle of the posterior lobe of the pituitary gland. 3 parts. J. Am. Chem. Soc., **50**: 573–601. 1928.

(13) Macy, I. G., Huncher, H. A., Donelson, Eva, and Nims, Betty. Human milk flow. Am. J. Diseases of Children, **39**: 1186–1204. 1930.

(14) Maxwell, A. L. I. and Rothera, A. C. H. The action of pituitrin on the secretion of milk. J. Physiol., **49**: No. 6, 483–491. 1915.

(15) McCandlish, A. C. The possibility of increasing milk and butterfat production by the administration of drugs. J. Dairy Sc., **1**: 6. 1918.

(16) McKenzie, K. An experimental investigation of the mechanism of milk secretion, with special reference to the action of animal extracts. J. Exp. Physiol., **4**: 305–330. 1911.

(17) Oliver, G. and Schafer, E. A. On the physiological action of extracts of the pituitary body and certain other glandular organs. J. Physiol., **18**: 277–279. 1895.

(18) Ott, Isaac and Scott, J. C. The action of infundibulin upon the mammary secretion. Proc. Soc. Exp. Biol. Med.. **8**: 48–49. 1910.

(19) Petersen, W. E., Palmer, L. S. and Eckles, C. H. The synthesis and secretion of milk fat. I. The time of milk and fat secretion. Am. J. Physiol., **90**: 573. 1929.

(20) Ribbert, Hugo. Über Transplantation von Ovarium. Hoden und Mamma. Arch. Enwick, Mechanik der Organismen, **7**: 688–704. 1898.

(21) Routh, A. Parturition during paraplegia, with cases. Trans. Obstet. Soc. London, **34**: 191. 1897.

(22) Schafer, E. A. On the effect of pituitary and corpus luteum extracts on the mammary gland in the human subject. Quart. J. Exp. Physiol., **6**: 17–19. 1913.

(23) SCHAFER, E. A. Note on preceding paper by Simpson and Hill. "The mode of action in pituitary extract on the mammary gland." Quart. J. Exp. Physiol., **8**: 379. 1915.

(24) SELYE, H., COLLIP, J. B. AND THOMSON, D. L. Nervous and hormonal factors in lactation. Endocrinology, **18**: 237–248. 1934.

(25) SIMPSON, S. AND HILL, R. L. The effect of repeated injections of pituitrin on milk secretion. Am. J. Physiol., **36**: 347–351. 1915.

(26) SIMPSON, S. AND HILL, R. L. The mode of action of pituitary extract on the mammary gland. Quart. J. Exp. Physiol., **8**: 377–378. 1915.

(27) STEHLE, R. L. A new method for separating pressor and oxytocic substances from the posterior lobe of the pituitary gland. J. Biol. Chem., **102**: 573–590. 1933.

(28) SWETT, W. W., MILLER, F. L. AND GRAVES, R. R. Quantity of milk obtained from amputated cows udders. J. Agr. Res., **45**: 385–400. 1932.

(29) TGETGEL, B. Untersuchungen über den Sekretions-druck und über das Einschiessen der Milch im Euter des Rindes. Schweiz. Arch. f. Tierh., **68**: No. 6, 335–348 and No. 7, 369–387. 1926.

(30) TURNER, C. W. The comparative anatomy of the mammary glands. Univ. of Mo. Cooperative Store, Columbia, Mo. Chap. 6, pp. 70–73. 1939.

(31) TURNER, C. W. AND SLAUGHTER, I. S. The physiological effect of pituitary extract (posterior lobe) on the lactating mammary gland. J. DAIRY SC., **13**: 8–24. 1930.

(32) ZIETZSCHMANN, O. Etude sur les vaches qui "retiènent" leur lait. Le Lait **II**: 229. 1922.