

THE
JOURNAL OF
COMPARATIVE PATHOLOGY
AND
THERAPEUTICS.

VOL. XXIII.—No. 3. SEPTEMBER 30, 1910. PRICE 2s. 6d.

THE STRUCTURE OF THE REPRODUCTIVE ORGANS
IN THE FREE-MARTIN, WITH A THEORY OF
THE SIGNIFICANCE OF THE ABNORMALITY.¹

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THE apparent prodigality with which Nature provides for the reproduction of plants and animals has a marked exception in the case of sterile organisms, often produced on a large scale, in which every function except that of propagation may be carried on in a quite perfect manner. The cases of the sterilisation of an organism are best seen in insects, but I wish at present to consider its occurrence high up in the animal kingdom in the well-known case of the free-martin, an apparent sterile cow born co-twin with a potent bull.

The nature of the free-martin is considered one of the unsolved problems of anomalous sex. John Hunter, who first drew attention to it, speaks of it as an unnatural hermaphrodite. "Hermaphrodites may be divided," he says, "into two kinds, the natural and the unnatural. The natural hermaphrodite belongs to the inferior and more simple genera of animals, of which there is a greater number than of the more perfect: just as animals become more complicated, have more parts, and each part is confined to its particular use, a separation of the two necessary families for generation has taken place" (*op. cit.*, p. 46). Sir James Simpson, in his well-known paper, after enumerating the paradoxes in the knowledge at that time of the

¹ Reprinted from the "Proceedings of the Royal Society of Edinburgh," Vol. XXX., Part III.

free-martin, says in conclusion: "The whole series of circumstances, when considered in conjunction with each other, seems to form, in relation to the origin of malformations, one of the strangest and most inexplicable facts to be met with in the study of abnormal development" (*op. cit.*, p. 835).

Spiegelberg looked on the free-martin as a transverse hermaphrodite, and Geddes and Thomson say: "No theory has yet explained the facts of this case" (*op. cit.*, p. 41).

The explanation I wish to bring forward is based on the views expressed in a previous paper on Mendelian Action on Differentiated Sex.

I must first describe the free-martin, next consider the facts known as to it, and then give my view as to its anomalous sex-condition.

The free-martin is a sterile twin, usually co-twin with a potent bull.¹ It has, in this case, the lower part of its genital tract to the naked eye like that of a cow, the upper part defective, and is usually considered as a cow sterile from incomplete development of its upper vaginal and uterine tract.

John Hunter described three specimens:—

(1) *Mr Arbuthnot's Free-Martin* (*op. cit.*, p. 52).—This animal was seven years old; went with the cows and bull; never showed any desire for either. The external parts were rather smaller than in the cow; the vagina was contracted above the urethral opening, becoming continuous with a small canal; uterus with two horns, two ovaria, and two testicles: vasa deferentia to the testicles; the left one did not come near the testicle, the right one only came near to it but did not terminate in the epididymis. They were both pervious, and opened into the vagina near the urethra. Vesiculæ seminales were present, smaller than in the bull; "the ducts opened along with the vasa deferentia." "This was more deserving of the name hermaphrodite than the following, for it had the mixture of all the parts, although all were imperfect."

(2) *Mr Wright's Free-Martin*, (fig. 1), five years old (*op. cit.*, p. 53).—This animal was more like the ox or spayed heifer than the bull or cow. The vagina had a blind end near the urethral orifice; a two-horned uterus; testicles, and no ovaria; these based on their size nearly equal those of a bull. Vesiculæ seminales opening into vagina, but nothing like vasa deferentia; a clitoris was present. "This animal cannot be said to have been a mixture of all the parts of both sexes."

(3) *Mr Well's Free-Martin* (*op. cit.*, p. 54).—Three to four years when killed, more like a heifer; no desire for male. Beginning of vagina as in cow, but obliterated beyond the urethra, although a solid part was continued. Two horns and two ovaria; vas deferens in interrupted portions. Between vagina and bladder the vesiculæ seminales, and between them the termination of the vasa deferentia. "This could not be called an exact mixture of all the parts of both sexes, for here was no appearance of testicles (*op. cit.*, p. 54). He thus considered Arbuthnot's case to have testes and ovaries, Well's case to have ovaries, and Wright's case testes.

Sir James Simpson, in the paper already quoted on The Alleged Infecundity of Females Born Co-twin with Males, states as his con-

¹ The reason for this limitation will be seen afterwards.

clusions that the human female co-twin with a male is as likely to be fertile and have as many children as the normal woman not a twin (*op. cit.*, p. 835).

The third paper I have now to consider is one by Professor Otto Spiegelberg, the late distinguished obstetrician of Breslau, who examined the parts carefully by the naked eye and microscopically in a free-martin full-time calf, and threw great light on the nature of the free-martin by showing that it was an imperfect male calf and not an imperfect female calf. Spiegelberg had, of course, the advantage over Hunter and Simpson of the more advanced knowledge of his time in microscopical technique and embryology. Rueff also noted in two cases that the sexual glands were testes (1851), and Gurlt in 1832 states the same.

Spiegelberg's cases were two in number, and are briefly as follows:—

Case 1.—This was one of twin calves killed a few days after birth. Externally, both calves seemed normal. The male had the



FIG. 1.

One of Hunter's free-martin cases. It has the head and horns of the ox or spayed animal, but the fore and hind quarters of a bull. Rudimentary nipples are present.

testes in the scrotum, and the internal genitals were quite normal. In the apparent female there were no traces of uterus, tubes, and ovaries (*nichts von Uterus, Tuben und Ovarien*); instead there was a special complex of organs, which, beginning a little distance from the kidneys in a peritoneal fold, ran down between the rectum and bladder (fig. 2). There the external genitals are opened from the front and turned to the side. Vulva and clitoris normal; the former passes into a narrow canal $1\frac{1}{2}$ inches long and 1 inch broad, with smooth walls, on whose anterior wall the urethra opens, and is accordingly the vestibule. No trace of the openings of Gartner's canals was evident. At the apex of the canal is an opening the size of a linseed, with no bridge of hymen, through which one can carry a sound up and back into a cavity scarcely an inch long. The wall of this cavity is half an inch thick, with connective tissue and transverse muscular fibres. Laterally from this rudiment of the vagina there run up two hollow processes, blind above, about 15 lines long; below, they unite with the wall of

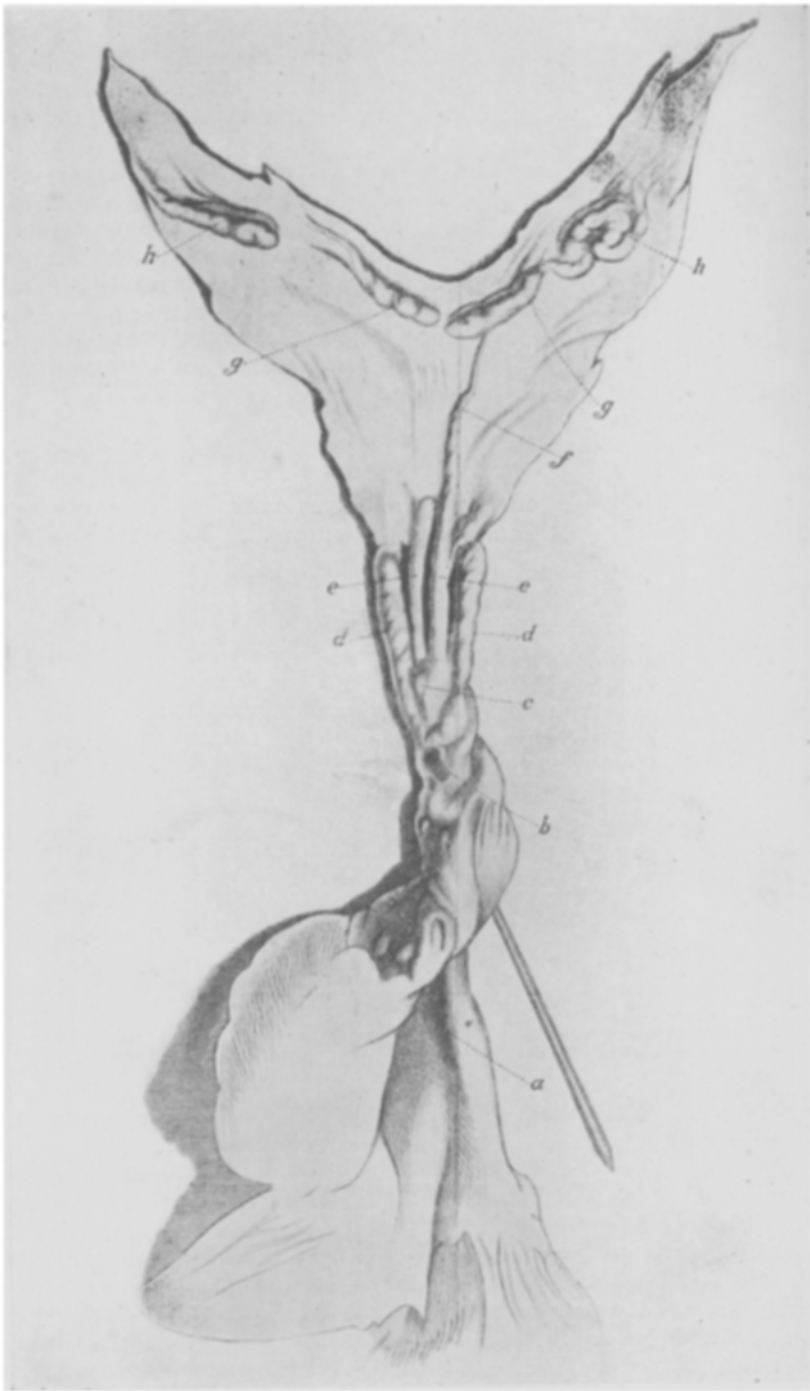


FIG. 2.

Genital Organs in Full-time Free-Martin Calf (Spiegelberg) (1).

a, Urinogenital sinus laid open from the front and turned back: a sound is passed into the Mullerian non-potent element with the knob ending at *c*, the uterus; *d d*, Vesiculæ seminales; *e e f*, Vasa deferentia; *g g*, Imperfect testes; *h h*, Wolffian bodies. In John Hunter's free-martin cases, Owen suggested that in what Hunter figured as double and differing sexual glands, one might be Wolffian body (*vide* Palmer's edition of Hunter, with Owen's Notes).

the cavity, and have the knob of the sound *c* between them; above, they end free in the connective tissue; both have a narrow lumen, blind at both ends. Between them lie two cords close to one another, *e* springing from the upper wall of the vagina; the left, 16 lines long, loses itself in the peritoneal fold; the right runs tortuously up as a fine thread, ultimately to a structure *g*. Both cords form a relatively wide canal, from which a few drops of white, slimy fluid can be squeezed. The canals are closed at both ends; *f* is solid. At the upper end of this arrangement there lie on each side two structures, at first glance the sexual glands. The vulvar canal is thus vestibule or female urogenital canal: the cavity *b* is rudimentary uterus; *d d* are rudimentary vesiculæ seminales; *e* and *f* vasa deferentia; the double organs *g* and *h* not ovaries and testes, but testes and rudi-

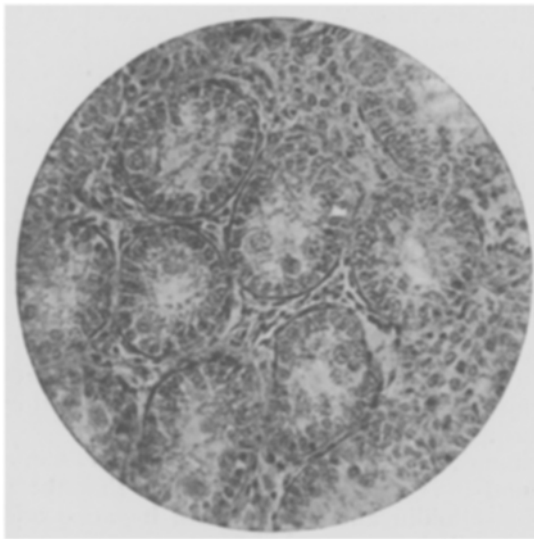


FIG. 3.

Sexual gland in Hunter's free-martin; tubuli seminiferi, slide 678.

mentary tubes, with a canalicular structure. The testes are thus seen at *g*, and at *h* rudimentary portions of the Wolffian body.

Spiegelberg considers this to be a case of transverse hermaphroditism in a bull calf, the upper part being male and the lower female in type. He summarises the literature carefully, and concludes that "if the twins are both female or of a different sex, their sexual organs are, as a rule, well developed; if both male, then frequently one is hermaphrodite." ("Sind die Zwillinge weiblich oder verschiedenen Geschlechts, so sind ihre Geschlechts-organe in der Regel wohlgebildet; sind sie beide männlich, so ist sehr häufig das eine derselben ein Hermaphrodit" (*op. cit.*, S. 130).)¹

Spiegelberg quotes Numan's article in the *Journal Vétérinaire et Agricole de Belgique par Brognier, etc.*, année 1844, as a valuable

¹ Case 2.—In this case Spiegelberg found the twins of different sex and normal. They evidently came from separate zygotes.

contribution. This it undoubtedly is, as I have found on studying it.¹

The summary given by Spiegelberg of Numan's conclusions is as follows:—

(1) If a cow has twins of different sex the female calf has almost invariably incompletely developed organs and is sterile.

(2) This fact based on observations has exceptions, and cannot be considered as indicating an exclusive law.

(4) The developmental error of the genitals does not happen exclusively to the female of similar twin couples, but occasionally to the male, and then the female is well developed: such cases are, however, rare.

(5) Multiple births are frequent in cattle, and, so far as the female is concerned, are to be considered the most certain and constant cause of sterility; the more so as the condition of the sexual organs which causes the anomaly does not as yet seem to have been observed in simple born calves. One finds, however, sometimes in such cases incomplete organs in a male.

The conclusion stated under (4) is the most novel, as it points to a free-martin with a sound female twin. It is of great interest theoretically in regard to mendelism in this connection. The necessary modification of (1) will be seen presently.

As Hunter's specimens are still in the Museum of the Royal College of Surgeons, London, it was therefore a matter of great interest that the sexual glands should be examined microscopically. This has just been done under the direction of Dr Arthur Keith, the Curator, and by permission of the Council; and I am greatly indebted to Dr Keith for permission to examine the slides and make microphotographs. I was able also to see the naked-eye specimens themselves during a visit I paid to the museum.

These specimens, although now about 140 years old, are in perfect preservation, and it is still more remarkable that the microscopical sections, cut in celloidin and stained with logwood and eosin, show even the finer details in a recognisable manner.

The special fact that emerges is that all the sexual glands are testes in Hunter's cases, that adjacent structures are epididymis, and that in none of the sexual glands are ova present. The characteristic testicular tissue is in the form of tubuli seminiferi, and in only one are spermatozoa present. They thus show the condition usually found in undescended testes in man and in the testis normally before descent is complete. I add a report of Hunter's specimens, and the structures are illustrated in the figures given.

¹ Numan's monograph was entitled "*Verhandeling over de onvruchtbaren rundern bekend onder den naam van Kweeven*," etc., met 23 platen; Utrecht, N. van der Monde, 1843. This monograph is not accessible in this country, so far as I have been able to ascertain. It is translated in the "*Journal Vétérinaire et Agricole de Belgique*" for 1844, and a copy of this was obtained by the Royal College of Physicians, Edinburgh. All the references to Numan's plates are given, but, unfortunately, not the plates themselves. Numan figures nine specimens, of which six are the same as Hunter's, but three show the sexual glands in the free-martin to be evident testes with the Müllerian element much less represented. A rudimentary preputial sheath is present in the latter, so that the animal is very like a bull. Numan terms the six like John Hunter's specimens "*Heifer Free-martins*," and the three remaining as "*Steer Free-martins*." He considers only the six as heifers, but all the nine are sterile bulls. He figures the vesiculæ seminales in all, but considers them in the six heifers as diverticula of Gartner's canal. In the points as to the sexual glands and vesiculæ seminales he is in error, but his whole monograph is a very able and valuable one.

The examination of the slides prepared from John Hunter's free-martin specimens gave the following results:—

Slide 678, testes with tubuli seminiferi; 682, epididymis; 686, epididymis and testes; 688, epididymis; 689, testes and hydatid testis (Müllerian); 690, testes; 691, testes and hydatid testis; 692, testes (Arbuthnot); 693, testes (Wright); 694, testes, scanty elements. In 691 the Müllerian hydatid is well shown (*vide* figs. 4 and 5).

It seems to me, therefore, fully established that the free-martin, when the co-twin is a potent male, is a sterile male, and not a sterile

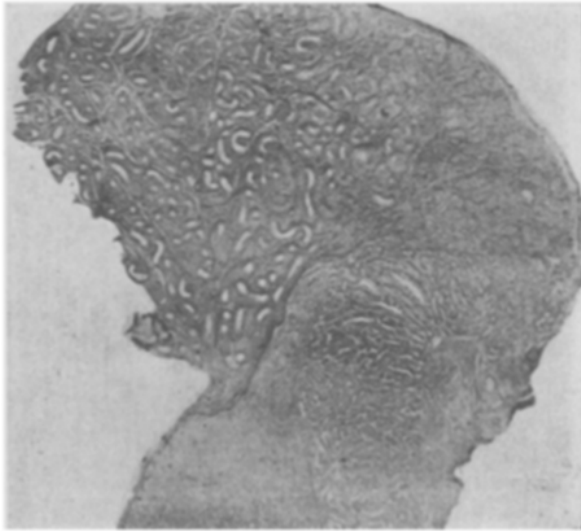


FIG. 4.

Sexual gland in Hunter's free-martin; epididymis in upper left angle, with Müllerian epithelium and glands below (hydatid testis, slide 691).

female, *i.e.*, they are identical male twins except in their genital tract and secondary sexual characters.

The following table shows the main cases (thirty in number) I have been able to collect.

[TABLE.]

Author.	Conditions of Organs.	Remarks.
John Hunter (1786).	(1) <i>Arbutnot's Free-martin</i> . Vagina, upper part narrow; testes; two cornua; vasa defer., vesiculæ seminales.	
	(2) <i>Wright's Case</i> . Vagina with blind end; two horns; testes really, external parts like cow; clitoris.	"More the appearance of the ox or spayed heifer" (<i>op. cit.</i> , p. 53).
	(3) <i>Well's Case</i> . Teats and udder small; vagina as in (1); vagina and uterus not pervious; testes; vasa deferentia; segments of vesiculæ seminales.	More like a heifer; no microscopic examination made of the tissues.
Numan (1843).	Describes nine cases: six like Hunter's and three somewhat different.	
Spiegelberg (1861).	External genitals and urinogenital sinus as in cow; rudimentary vagina and uterus; parts of seminales and vasa; parts of W. bodies; testes rudimentary (microscopical examination).	Potent bull twin and free-martin calves slaughtered one day after birth; microscopical examination of structures.
Rueff.	Three cases: two had testes; no vesiculæ seminales; external genitals female; vagina (?) blind in all three. <i>Rep. d. Thierheilk. von Hering</i> , 12 Jahrg. 1851, p. 103.	
Hering.	Two cases: data only in one. No genitals apart from vagina. ("Ausser der Scheide nichts von Genitalien vorhanden gewesen und von Grunde jener, blos eine dünne Falte des Bauchfells nach beiden Seiten hin abgegangen sein.")	
Anonymous.	In Fuchs' <i>Thierärzt. Zeitung</i> , Jahrg. iii., note given of five female calves from twins with defective uterus.	
	In another, note is made by Fuchs of a preparation at the Carlsruher Vet. School, of case with both male and female genitals.	
Scarpa.	One-year-old animal with external female genitals and internal male.	Presence of twin not stated in Spiegelberg's summary.
Gurlt.	Conditions like Spiegelberg's; union between testis epididymis and vas more evident.	
Allnatt.	Vagina long cul-de-sac with rudimentary uterus; solid vesiculæ seminales; vas ended in prostate.	
Simpson, J. Y. (1844)	Mentions dissection of two adult and one calf free-martin, all like Hunter's cases. Quotes also a case of Allen Thomson's, <i>Simpson's Obst. Mem.</i> , i. p. 823.	Allnatt states that he was informed of cases where sexual desire was not absent in the free-martin. (There is no reason why it should be absent as a rule, as the testes are usually represented).
	In <i>Todd's Cyclopædia</i> , he quotes a free-martin where he found testicles.	Simpson does not consider the question of the female calves co-twin with males and fertile as being derived from separate zygotes. This mistake was due to the still current error of holding that sex is not determined, as it really is, on fertilisation, but by subsequent changes in the zygote.
		A free-martin is derived along with its potent twin from one zygote.

I have now to explain how the free-martin arises; and in considering this, the cardinal fact must be kept in mind that the potent and sterile twins arise from one zygote, not from two, and that the genitals of each have to be provided from a single zygote, which normally might give rise to one perfect male. Simpson's mistake in his paper was his not recognising that a male and female twin, perfect in development, arise from separate zygotes.

I must now consider—

- (1) The general anatomy of the genital tract in the female calf.
- (2) The action of mendelism in producing the free-martin condition.
- (3) Consideration of the view that the free-martin is a transverse hermaphrodite.
- (4) Summary and literature.

(1) *The General Anatomy of the Genital Tract in the Female Calf.*

This consists of ovaries, Fallopian tubes, cornua, vagina (Müllerian and urinogenital sinus), urethral opening, lateral folds of skin comparable with the human labia majora and minora, and of the glans phalli. The vagina is urinogenital sinus in its lower half and Müllerian in its upper. The urinogenital sinus portion is the lower end of the anterior division of the pars penultima of the primitive gut or entodermal cloaca of other investigators. The lower half of the effective vagina is thus urinogenital sinus, and this must be carefully noted. Developmentally, the sexual glands and urogenital tracts in boves arise as in allied mammals, *i.e.*, we have Wolffian bodies, etc., and on these the ovaries or testes develop; subsequent changes in the Wolffian bodies and ducts give us in the female a persistent Wolffian duct, the canal of Gartner, instead of its uppermost and lowest segments as in most mammals; while the ducts of Müller give the vagina tubes and cornua. The urinogenital sinus, urethra, and bladder arising from the anterior coronal division of the pars penultima of the primitive gut make up the rest of the tract. The ova and spermatozoa arise by reduction from the primitive germ-cells, and these arise not from the germ epithelium but from the primitive germ-cell mass, itself a part of the unreduced zygote in its earliest stage. This view of the origin of the gametes may be termed the zygotic origin of the gametes, or Owen-Weismann law.

In the normal female bovine tract we have not only the potent elements (ovary, cornua, and vagina), but also the epoöphoron with more than the ductus epididymis, *viz.*, the whole Wolffian duct. We have thus in the female the equivalents of the epididymis and vas deferens of the male. These are not functionally active, and histologically are degenerated, but are quite recognisable in the broad ligament.

In the normal bovine male we have not only the potent male organs, but also the hydatid testis (Müllerian duct) and the prostatic utricle, the equivalent of the hymen usually, and a varying amount of degenerated female genital structures.

These potent and non-potent elements of the developed tract mean casual unit-characters in the zygote, of unequal value, usually coupled in the human male and autonomous, dominant and recessive in their nature, and it is by their separation or segregation into the

soma of the potent male and sterile male (free-martin) that we get the explanation of this anomaly.

(2) *The Action of Mendelism in producing the Free-Martin.*

When a male zygote twins we may get—

(1) Identical male twins.

(2) One perfect male and one sterile male, the free-martin.

In (1) there is an equivalent division of genital and somatic determinants, and identical twins is the result.

How do a perfect male and an imperfect male arise?

In the free-martin (2) there are present, as Spiegelberg shows, urinogenital sinus, rudimentary vesiculæ seminales, very rudimentary vagina and knob of uterus; testes and Wolffian bodies, both imperfectly developed.

Now, as already said, we have to account for the genital organs in

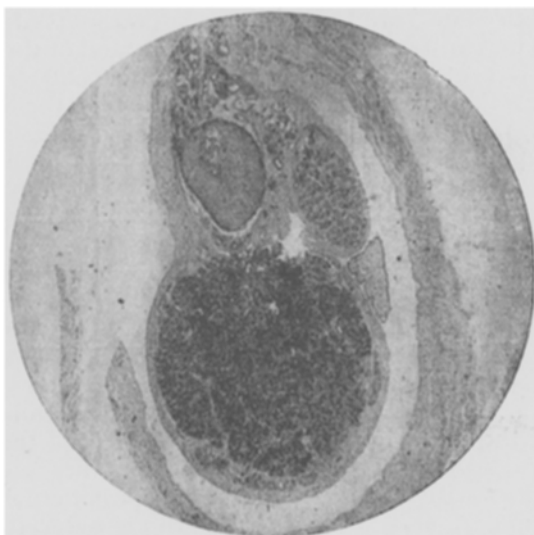


FIG. 5.

Testis in scrotum of newly-born human fetus. Testis is below; above, on the right side, is seen the hydatid testis unattached and then epididymis attached. To left of epididymis lies accessory suprarenal body.

the potent bull and free-martin from one zygote—a male zygote. Had this male zygote developed a single bull, it would have had potent male organs (testes and phallus) and non-potent female ones, viz., Müllerian hydatid attached to the testis, and prostatic utricle, the analogue of the hymen, with a varying amount of the rest of the female Müllerian tract. When the twinning of a male zygote in black cattle takes place, this potent and non-potent complex of the genital organs may be divided so that the potent part goes to the potent bull-calf, the non-potent to the free-martin. This being the general scheme of the division, we must now account as exactly as possible for the various parts in the genital tract of the free-martin in Spiegelberg's case, and these may be grouped as follows for explanation: (a) testes; (b) urinogenital sinus and external genitals;

(c) rudimentary vagina ; (d) vesiculæ seminales, vasa deferentia, and Wolffian bodies.

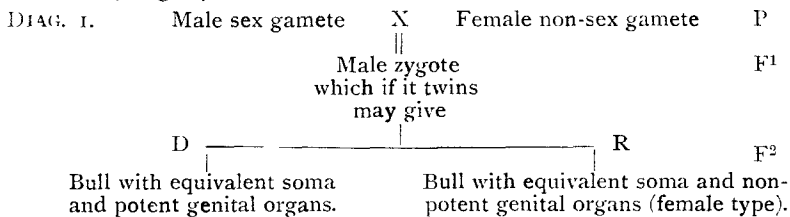
(a) *Testes*.—The male zygote gave, of course, sperm-germ cells in the sperm-epithelium of its Wolffian ridges, and the future testes became divided between the twins. This division took place most probably after the primitive sperm-cell mass had formed. The testes are undescended.

(b) *Urinogenital Sinus and External Genitals*.—The former is probably derived from the somatic division of the twins. The labia and glans are non-potent elements.

(c) *Rudimentary Vagina and Uterus*.—These are undoubtedly derived from the Müllerian hydatid and prostatic utricle (fig. 5).

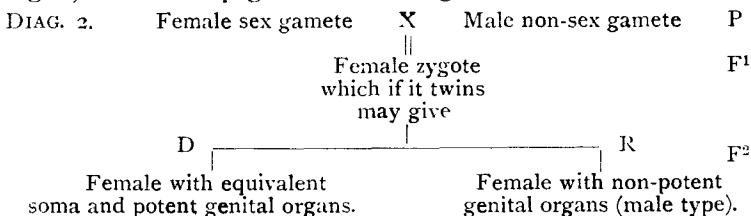
(d) *Vesiculæ Seminales, Vasa Deferentia, and Wolffian Bodies*.—The first two arise from the Wolffian ducts which are present and derived from the non-potent elements ; and the Wolffian bodies are given in somatic division.

Thus the free-martin with a potent bull twin is the result of a division of a male zygote, so that the somatic determinants are equally divided, the genital determinants unequally divided, the potent going to the one twin, the potent bull, the non-potent genital determinants to the free-martin. The potent organs are dominant, the non-potent recessive, and the Mendelian scheme may be figured as follows (diag. 1):—



In three of Numan's cases the sterile twin had testes and a rudimentary preputial sheath. This is a rare free-martin where the Müllerian elements remain in the potent bull, but the preputial element of the external genitals is thrown into this variety of free-martin. There are thus two varieties of bull free-martin, viz., John Hunter's free-martin (so-called heifer free-martin) and Numan's free-martin (steer free-martin).

Before I knew of Numan's paper, I saw that there should be also in Mendel's scheme a free-martin with a potent female.¹ I could admit this as a possibility not yet demonstrated, but Numan's cases show its existence clinically, and indicate the value of the Mendelian scheme and the Owen-Weismann law in studying anomalous sex. This very rare occurrence is shown in the Mendelian scheme (diag. 2). We rarely get the following:—



As yet there is no actual anatomical demonstration, but Numan gives one of these.

One point not yet determined so far is as follows :—

While the vaginal and uterine rudiments in the free-martin are undoubtedly derived from the normal non-potent elements of the normal male segregated as a recessive element, as in F^2 of Mendel's crossing pea-experiments, I am in doubt yet as to whether urino-genital sinus and the external genitals are derived from these or from a division of the soma.

(3) *Consideration of the View that the Free-Martin is a Hermaphrodite.*

I may remark here that the non-potent elements in the human genital tract vary in amount. Normally in the male we have only the prostatic utricle and hydatid testis (Müllerian), but occasionally we have the non-potent organs more extensive, producing a uterus and vagina in a male, as in Shepherd's case. These are described as tubular or transverse hermaphrodites. They are not hermaphrodites at all, as no organism is hermaphrodite if the sexual glands are similar. Such anomalies are due to an excessive amount of the non-potent elements; and as these are of the opposite sex type, they give rise to the idea of hermaphroditism. Free-martins thus are not hermaphrodite, and the term pseudo-hermaphrodite means nothing.

(4) *Summary and Literature.*

General Conclusions.—Nature can thus, in a very simple and effective way, sterilise an organism. The zygote, male or female, is, for this purpose, unequally divided by twinning (or otherwise in single cases), so that only recessive or non-potent genital determinants are allotted to the one twin, and in this way sterility is absolutely secured.

On one point we have as yet no information, viz., as to whether or not the potent bull co-twin with the free-martin has its prostatic utricle normal. Theoretically it seems to me this may be defective or wanting, but here actual dissection is necessary.

The free-martin is, according to Mendelian phraseology, a pure or extracted recessive *quâ* its genital determinants, and the potent twin a pure or extracted dominant, both of F^2 in the Mendelian scheme. Occasionally, but very rarely, as in three of Numan's cases, the recessive element is less complete.

The potent bull alone can have offspring, and some of its males must breed true to the dominant genital determinants, in certain cases at any rate, as Mendel's scheme demands and theory indicates. This will introduce a variation, *i.e.*, we may get a bull not possessing a hydatid testis, and thus varying from the normal bull, and we get here one factor in the mechanism of variation; but I defer the consideration of this.¹

According to J. A. H. Murray, the origin of the term "free-martin" is unknown. In Holland they are termed "kween," and in Brabant "bouquetin"; in France "taur"; in ancient Rome "taura" was the

¹ Observations are still needed on such specimens. We need to know the exact condition of the organs in the potent animal, and this could best be done if such twin calves or specimens obtained in the cornua of slaughtered animals were examined as to details. Free-martins are not uncommon, but in Hunter's days they were obtained from the farm and a history given; now, in the large sales where animals are bought, the history can seldom be obtained.

term (Simpson and Spiegelberg). According to Simpson and others, the Romans did not seem to have been aware of the association of the "taura" with twinning.

I have to thank Professor J. Arthur Thomson for valuable references, and Mr Henderson for one undoubted specimen.

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REPORT ON EXPERIMENTS WITH THE WILD PASSION-FLOWER VINE IN CONNECTION WITH THE DEATH OF CATTLE IN THE BEAUDESERT DISTRICT (QUEENSLAND).

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FOR a number of years, especially during the dry season, considerable loss has been sustained by cattle owners in the scrub belts near Beaudesert owing to the death of numbers of their stock, both in milking herds and in working bullocks.

According to the District Stock Inspector's Report the trouble has occurred year after year, and a large number of the cattle have died from some unknown but apparently identical cause, as the