about 0.15 M. They will not exceed however those on the Suez-canal with a strong wind.

For the last 16 K. M. of such an open canal the maximum velocities at springtide may be somewhat more considerable. On account however of the great width, which may be given to this part they will cause no serious difficulty.

Therefore, if we assume, as we have good reason to do, that even at spring tide and with wind the velocities of the current on the Suez-canal offer no serious difficulty to navigation we may conclude that on a Panama-canal of the above description also navigation will experience no difficulties on account of the velocities of the current.

Therefore, *if we leave out of consideration* the question whether an open Panama-canal without tidal lock is to be preferred either to a sea-level canal with such a lock, as proposed by the Board of Consulting Engineers, or to a summit level canal with three locks, as is now in course of execution, we may conclude, in the main in conformity with the conclusion of the French Academy of Sciences of 1887, but for different reasons:

That the velocities of the current due to tidal motion in an open Panama-canal without tidal lock will be no obstruction to navigation.

Zoology. — *"On the formation of red blood-corpuscles in the placenta of the flying maki (Galeopithecus).* By Prof. A. A. W. HUBRECHT.

(Communicated in the meeting of March 30, 1907).

At the meeting of November 26, 1898, I made a communication on the formation of blood in the placenta of Tarsius and other mammals, which was later completed by a more extensive paper, containing many illustrations (Ueber die Entwicklung der Placenta von Tarsius und Tupaja, nebst Bemerkungen über deren Bedeutung als hämatopoietische Organe; Report 4th Intern. Congress of Zoology, Cambridge 1898). The facts observed by me and the interpretation founded on them, have not until now been generally accepted, and in a recent very extensive discussion of the position of the problem concerning the origin of the red blood-corpuscles in the 14th volume of the "Ergebnisse der Anatomie und Entwicklungsgeschichte" (Wiesbaden 1905), by F. WEIDENREICH, the author, when mentioning my views, emits the supposition that I mixed up phagocytic and haematopoietic processes.

This conclusion was not based on a renewed and critical examination of the material, studied by me. I have regretted this, since I have pointed out clearly and repeatedly that the numerous prepara-

tions at Utrecht concerning this and other embryological problems are always available for comparative and critical work, also for those who do not share my views. Moreover it appears from the literature, mentioned in WEIDENREICH's paper, that the more extensive and illustrated article, quoted above, has remained unknown to him.

All this would not have induced me to return to this subject once more, were it not for the fact that during the last months I have become acquainted with the placentation-phenomena of a totally different mammal in which these phenomena have never yet been studied, namely Galeopithecus volans, which, like Tarsius, Nycticebus, Tupaja and Manis, was collected by me in the Indian Archipelago in 1890—1891 as extensively as possible for embryological purposes. During the first origin of the placenta of this rare and in many respects primitive mammal [1]), phenomena are observed which elucidate the process of blood-formation in the placenta in such an uncommonly clear manner that in this case it will be difficult to deny the evidence.

The formation of blood in the placenta of Galeopithecus may be said to take place according to a much simpler plan than in Tarsius, although the principal outlines remain the same and here also the non-nucleate haemoglobine-carrying blood-corpuscles must be regarded not as modified cells but as nuclear derivatives. Likewise the placenta of Galeopithecus bears testimony that not only the maternal mucosa but also the embryonic trophoblast takes part in the blood-formation, while the thus formed blood-corpuscles — also those that are furnished by embryonic tissue — circulate in the maternal blood-vessels only.

In Galeopithecus the process is simpler especially in this respect that here no megalokaryocytes play a part in the formation of blood, so that it is less easy — as WEIDENREICH did — to regard blood-corpuscles that are set free (such as we notice it in Tarsius, when the big lobed nuclei of these megalokaryocytes disintegrate) as being on the contrary devoured in that moment by phagocytosis! [2])

The haematopoiesis is started in Galeopithecus in the following manner. At about the same time that the young germinal vesicle, which has just gone through the two-layered gastrulation stage (gastrulation by delamination [3])), has attached itself to the surface of the strongly folded and swollen maternal mucous membrane, this mucous

[1]) W. LECHE is inclined (Ueber die Säugethiergattung Galeopithecus, Svenska Akad. Handl. Bd. 21, N°. 11, 1886) to see in Galeopithecus a form which must be placed in the neighbourhood of the ancestral form of the bat.

[2]) Sectional series of Tarsius of a later date give a still clearer image than those which served for my figures of 1898.

[3]) See on this point Anatomischer Anzeiger Bd. 26, 353.

membrane reacts in the manner, well-known in other mammals (Tarsius, hedgehog, rabbit, bat,. etc.) by perceptible changes in the uterine glands in the vicinity of this place of attachment and by the formation of so-called trophospongia-tissue, consisting of a modification of the interglandular connective tissue, to which are added proliferations of uterine and glandular epithelium.

As the final product of these preliminary phenomena we now see that a part of the maternal mucosa where the germinal vesicle has coalesced with the mucosa, presents a more compact proliferation, while nearer the periphery the uterine glands, by strong dilatation of their lumen, differ clearly from the other uterine glands, as this is also the case in Tarsius, Lepus and other mammals during early pregnancy. The dilated glands may be followed up to their mouth; this mouth, however, no longer connects the glandular lumen with the uterine lumen, since in this place the embryonic trophoblast has disturbed the connection and covers the mouths of the glands.

This trophoblast now also shows unmistakable signs of cell-proliferation, although it does not at once attack and destroy the maternal epithelium, as in the hedgehog, Tarsius, Tupaja, etc. but rather finds itself facing this maternal epithelium in full proliferation, in the manner stated by me also for Sorex [1]). Instead of being closely adjacent, however, spaces are left open from the beginning between trophoblast and trophospongia, which spaces are partly mutually connected and partly are subdivided into smaller compartments by trophoblastic villi, attaching themselves to the trophospongia-tissue.

In this manner the free surface of the trophoblast, facing the embryo, obtains a knobbed appearance. [2])

Already in early developmental stages, when there is as yet no question of the folding off of the embryo and long before blood-carrying allantoic villi have become interlocked with these trophoblastic villi for the further completion of the placenta, we find in the spaces between trophoblast and trophospongia numerous blood-corpuscles of which we can not say that they have been carried thither by maternal vessels exclusively, although there can be no doubt that a connection between these spaces and the maternal vascular system is established at an early date. In the manner, indicated above, these spaces communicate also with the uterine glands which are here dilated. And in these glands as well as in

[1]) Quarterly Journal of Microscopical Science, vol. 35.

[2]) Certain modifications which I observed when the germinal vesicle develops in a uterus which is still in the puerperal stage, may be left out of account here.

the interglandular tissue and in the cells, lining the just mentioned spaces, phenomena take place which force us to the conclusion *that a great number of these blood-corpuscles originate in loco.* When we follow these phenomena up to their earliest appearance, we find that in the dilated glands in many places compact cell-heaps are formed, which sometimes lie quite loose in the gland, but in other cases are still found in direct connection with the cell-lining of the gland. We must assume that this latter condition represents the original one and that consequently we have here an epithelial proliferation by which new cell-material is carried into the region of the future placenta.

The final product of these lumps of tissue, which in early stages appear so distinctly as cell-heaps, is an agglomerate of non-nucleated blood-corpuscles. The gradual transition of the nucleate cells into the blood-discs may be followed step by step by successively comparing preparations of the youngest and subsequent stages: often in one preparation all transitions are found together. It then appears that the conclusions I drew for Tarsius and Tupaja in 1898 are confirmed here, viz. that the blood-discs are produced by gradual transitions from the modified nuclei of the above-mentioned cell-heaps and that in this process transitional stages are generally found, comparable to what I called "haematogonia" in the above-quoted paper. They resemble polynuclear leucocytes from which they may be distinguished, however (also according to MAXIMOW and SIEGENBEEK VAN HEUKELOM; see report of the meeting of the Amsterdam Academy of Nov. 26, 1898), by certain characteristics. This phenomenon has been more fully investigated by POLJAKOFF, who also regards the non-nucleate corpuscles as nuclear derivatives and not as cells, deprived of their nuclei. In his paper [1]) numerous illustrations are given of stages corresponding to my haematogonia. It appears from the literature, mentioned by POLJAKOFF that my paper of 1898, preceding his publication, was unknown to him: the concordant results which we have obtained at an earlier date, are confirmed in a striking manner by the phenomena seen in Galeopithecus.

But blood-corpuscles are also produced by other sources besides these epithelial glandular proliferations. Between the dilated glands we find in Galeopithecus in the trophospongia-tissue very conspicuous groups of large cells with a big, but circular nucleus. They show a tendency to lie together in nests, which nests are more or less kept together by elongated cells, forming a spurious wall which distantly remind us of an endothelium.

[1]) Biologie der Zelle. In Arch. f. Anat. u. Phys. Abth. 1901. Pl. I and II.

These cells also are gradually dissolved into blood-corpuscles: as the uterus grows and the trophospongia passes through its successive developmental stages, they disappear: the blood-corpuscles which owe their existence to them, fall into the above-mentioned spaces, from whence they are taken up in the further circulation. The intermediate stages that can be observed in this way of blood-formation, are in fact an increase of nuclei by amitosis, as was also described by POLJAKOFF and later a gradual formation from these nuclear derivates of non-nucleated blood-discs.

To these two processes of blood-formation in the placenta of Galeopithecus a third must be added in which not the mother is the active agent, as in the two former cases, but the embryonic trophoblast. Of this trophoblast we described above how it forms the bottom of the cavities into which the newly-formed blood-corpuscles are discharged, and how it coalesces with the maternal trophospongia to such an extent that for many cells, which here are closely adjacent, it is impossible to determine whether they take their origin in the mother or in the trophoblast of the germinal vesicle.

Yet in regard to the wall of the cavities, which separates them from the lumen of the uterus, there can be no doubt that we have here trophoblastic tissue only. About the active proliferation of this trophoblast tissue there is no doubt, no more than about the question whether the numerous parts of this trophoblast that project into the cavities, partake in the haematopoiesis. As soon as these parts are examined with strong powers it is quite evident that here the nuclei of the trophoblast cells undergo similar modifications as were described above and that the final product of these modifications are again red non-nucleated blood-corpuscles which are added to those already present and originating from the mother. Now these corpuscles are, in the same way as I observed ten years ago in Tarsius and Tupaja, *set free into the maternal circulation and carried along by it.*

On the theoretical significance of the fact that the germinal vesicle takes an active and important part in increasing the number of units for the transport of oxygen in the maternal blood, I will not expatiate here.

And for the histological details of the formation of the bloodplates, resp. non-nucleated blood-corpuscles from an originally normal cell-nucleus, I refer to the coloured figures of pl. I and II of POLJAKOFF's paper in the 1901 volume of the Arch. f. Anat. u. Phys. (Anat. Abth.). With his illustrations I can identify everything I have observed in Galeopithecus. While in a very few cases there seems to be a possibility that the blood-corpuscle owes its existence to a

change of the nucleus *in its entirety*, in the vast majority of cases a distinct amitotic disintegration is observed, the number of fragments varying, but generally lying between three and five. As the already modified nucleus dissolves into these fragments the comparability with polynuclear leucocytes seems more obvious, and the colour as a rule approaches more and more to that which the blood-corpuscles themselves assume in the artificially fixed preparation. The same fact was stated by me also for Tarsius in 1898 and figured on Pl. 14 figs. 91—96.

Finally I point out, since my results and those of POLJAKOFF agree in so many respects, that also RETTERER in the volume for 1901 of the Journal de l'Anatomie et de la Physiologie (Structure, développement et fonction des ganglions lymphatiques, p. 700) has obtained similar results and is inclined to assume a still closer genetic relationship between polynuclear leucocytes and haematogonia when he declares that the leucocytes, liberated from lymphatic glands "finissent par se convertir, dans la lymphe ou le sang, en hématies grâce à la transformation hémoglobique *de leur noyau*..."

Thus my observations on Galeopitheous form a link in the chain, which begins with HEINRICH MÜLLER in 1845 (Zeitschrift für rationelle Medicin vol. 3. p. 260) was then continued and upheld by WHARTON JONES (Phil. Trans. 1846, p. 65 and 71) and HUXLEY (Lessons in Elementary Physiology, 1866, p. 63) and which, since in 1898 Tarsius added another link, has with increasing weight bound up the question of the origin of the non-nucleated blood-corpuscles in mammals to the conception that these elements in the mammalian body are not equivalent with cells, but must be regarded as nuclear derivatives.

(May 24, 1907).