n°. 15, with a length of 9 cm. As a new-born monkey measures 27 cm., that would be just a third part of the length. Now the third part of the length of a full term human foetus is 17 à 18 cm., which, according to RETZIUS, corresponds with the end of the 4th month.

When the ratios in length between the monkey embryos are thought similar to those which consist inter se between the human foetus, then with adequate development one should find the first indication of the origin of the fissura Sylvii, also in the embryos of man, only at the end of the 4th month.

Now the records of ECKER and RETZIUS are rather similar and they point out the third month as the period in which the first indication of this sulcus is found in human embryos. This should be therefore a month sooner than the analogous period in Semnopithecus.

The conclusions to which I think I may come, are therefore the following:

1. The fissura Sylvii in Semnopithecus commences on the lateral surface, and develops towards the lateral edge, which is the reverse in man.

2. The first that one sees of this fossa is a sulcus, to which later on, at the anterior side a second is added, both of which bordering the insular area temporal and frontalward.

3. The first indication of the commencement of this sulcus is found a month later than after the calculation in human foetus.

4. The total operculisation of the insula is found in Semnopithecus at the stage which would be reached for human foetus in the beginning of the 6th month.

Physiologie. — *"The Olfactology of the Methylbenzol Series"*. By Dr. E. L. BACKMAN from Upsala (for the present at Utrecht). (Communicated by Prof. Dr. H. ZWAARDEMAKER.)

(Communicated in the meeting of January 27, 1917).

What may be defined as an homologous series, is an arrangement of substances in the order of their atomicity which changes progressively and in a particular way in the same straight line. We know that such substances, when odorous, give a scent which also varies gradually and almost continuously, and evoke smell-sensations representing points upon an intensive scale like the atomic compositions. The question whether intermediate compensations occur between the terms of this scale is of general importance for physiology. Hitherto the stimulus-limina of the terms of only few

homologous series have been established (HAYCRAFT [1]), J. PASSY [2]), ZWAARDEMAKER [3]), and quite recently the electrical phenomenon (ZWAARDEMAKER [4])).

The present communication deals with the liminal stimuli of a series not yet investigated, the possible combinations within the series, the diffusion-rate, the adsorption to electrically charged metallic plates and the intensity of the vapour-electricity of the terms. We generally made use of ZWAARDEMAKER's experimental method [5]).

The just noticeable smell was determined in the smell-chamber (l. c. p. 56) by evaporating extremely small quantities of odorous matter in aqueous solution at a carefully maintained temperature in the space of 64 Litres. The determination did not take place before 3 or 4 minutes after complete volatilization. Between two determinations the chamber was aired and the adhering scent was removed from the walls by means of chalk and a towel. In the same chamber, now provided with a back-wall of filterpaper, impregnated with the saturated aqueous solution, we measured the diffusion. By repeated determinations we established the time required for a distinct sensation of smell in the centre of the opposite wall.

For a quantitative determination of the vapour-electricity produced by spraying the several terms, we employed a glass sprayer and a circular aluminium plate 20 cm. in diameter, connected to an EXNER-electroscope. The sprayer as well as the cap of the electroscope were earthed, the aluminium plate, however, had been carefully insulated by mounting it on a block of paraffin. Invariably 10 c.c. were sprayed under an overpressure of two atmospheres through compressed air. By establishing the capacity of the electroscope with receiving plate and the magnitude of the deflections at successive voltages the number of coulombs, obtained per c.c. as a charge on the plate, could easily be ascertained. Under these experimental conditions no charge was obtained by spraying pure water. Before performing the measurements we first searched for the optimal distance between sprayer and aluminium disc at which we could be sure of the maximal charge. The tables show the averages of the charges in coulombs per c.c. of sprayed liquid, calculated from the deflections of the electroscope.

The adsorption of the odorous substances was examined for elec-

[1]) HAYCRAFT. Brain II 1888 p. 166.
[2]) J. PASSY. Compt. rendus. Mai 1892, Mai 1893.
[3]) ZWAARDEMAKER. Die Physiologie des Geruchs. Leipzig, 1894 p. 238.
[4]) ZWAARDEMAKER. Proceedings Kon. Ak. v. Wetensch. May 27 1916. Vol. 25, p. 3.
[5]) Cf. TIGERSTEDT's Hdb. d. physiol. Methodik. Bd. 3 p. 46.

trically charged metallic plates. To this end the full scent, furnished by an olfactometric cylinder pushed off to its full length (l.c. p. 65), was sent for five minutes through a nickel-plated tube 10 cm. in length and 0,8 cm. in bore, while the insulated tube was charged to 220 volts. The metallic tube consisted of two parts insulated from each other, which, therefore, could be charged oppositely. When the five minutes had elapsed we tried to find out if any odour adhered to the wall and how long it remained there. Such was the rapidity at which the air was drawn through the olfactometric cylinder and the nickel tube that as much as 6 Litres passed every minute.

The determination of the odorimetric coefficients as well as the compensation- and combination-tests were performed with some of ZWAARDEMAKER's precision-olfactometers. The rapidity of the airstream was the same (6 Litres per minute); besides the smelling took place after the air had been streaming for precisely $^1/_4$ minute. At that moment the connection with the suction-pump was broken, the communication with the olfactometrical cylinder was arrested, smelling took place through a short side-tube at the reservoir, the latter of a capacity of about 100 c.c. Every experimental sitting comprised a number of tests of the same day together with those of previous days. Only the averages have been tabulated. The olfactometrical cylinders were invariably filled the previous day with a saturated aqueous solution of the terms of the homologous series.

Liminal Stimuli of the methyl-benzol series.

Benzol	5,3	10^{-6}	Grams per Litre of air
Toluol	2,0	10^{-6}	,, ,, ,, ,, ,,
Xylol	0,8	10^{-6}	,, ,, ,, ,, ,,
Pseudocumol	0,2	10^{-6}	,, ,, ,, ,, ,,
Durol	0,087	10^{-6}	,, ,, ,, ,, ,,

These values expressed in gram-molecules per Litre of air

Benzol	6,80	10^{-8}	gram-molecules per Litre of air
Toluol	2,17	10^{-8}	,, ,, ,, ,, ,,
Xylol	0,76	10^{-8}	,, ,, ,, ,, ,,
Pseudocumol	0,18	10^{-8}	,, ,, ,, ,, ,,
Durol	0,07	10^{-8}	,, ,, ,, ,, ,,

These determinations fully bear out HAYCRAFT's rule that in the homologous series of organic chemistry the smell-intensity at first gradually runs up as we pass from the lowest to the higher terms. By further addition of methyl-groups the amount of matter, required

to produce a just noticeable smell-sensation, gradually diminishes. The increment of smell-intensity is even approximately proportional to the number of methyl-groups. The smell-intensity of toluol is about three times greater than that of benzol, that of xylol about three times greater than that of toluol and that of pseudocumol about four times greater than that of xylol. The smell-intensity of Durol is only about twice that of Pseudocumol: the increment of intensity therefore, is smaller than might be expected from the ratios found previously. Most likely this is why on further methylation there is an absolute decrease of smell-intensity.

Diffusion-rate over a distance of 40 *cm. at* 19° *C.*

The time required for a perceptible smell-sensation set up by the terms of the series at a distance of 40 cm. is:

Benzol	1	min. 15	sec.
Toluol	1	„ 15	„
Xylol		60	„
Pseudocumol		60	„

Needless to say that, in order to determine the precise diffusion-rate also the tension of saturated vapour and the smell-intensity has to be taken into account.

Electrical charge by spraying.

First of all the charge of sprayed saturated solutions was determined. True, such solutions do not admit of easy comparison, the solubility in water of the members of the methyl-benzol series being widely different; still, the values serve our purpose technically.

I found the following:

	Optimal distance	Electric charge in coulombs per c.c.
Benzol	35 cm.	116.4×10^{-11}
Toluol	25 „	$92.1 \times 1.^{-11}$
Xylol	40 „	74.5×10^{-11}
Pseudocumol	35 „	32.3×10^{-11}
Durol	33 „	24.1×10^{-11}

The charges of sprayed equimolecular solutions can be readily compared. The two highest terms, however, are so little soluble, that the first term would not yield a charge in that extreme dilution. For this reason only groups should be examined in which the first three terms can indeed be taken equimolecular

Conc.		Optimal distance	Electrical charge in coulombs per c.c.
Benzol	$\frac{1}{1200}$ normal	30 cm.	18.9×10^{-11}
Toluol	$\frac{1}{1200}$ "	35 "	18.9×10^{-11}
Xylol	$\frac{1}{1200}$ "	43 "	28.7×10^{-11}
Pseudocumol	$\frac{1}{4800}$ "	35 "	18.4×10^{-11}
Durol	$\frac{1}{200000}$ "	35 "	18.0×10^{-11}

It will be seen that on further methylation the electrical charges of an equimolecular solution rise slowly at first, later on very rapidly. Parallel to this runs a progressive insolubility in water.

Adsorptivity.

The capacity of the terms of the methyl-benzol series of being adsorbed to charged or uncharged metallic plates is remarkably slight. Benzol is the only one that adheres to the metal wall in some measure, the other substances not at all.

Olfactometry (at the stimulus-threshold).

The olfactory values appeared to be the following:

Benzol	0.3 cm.	corresponding to the liminal values in gram-molecules found in a previous experiment (stimulus-threshold).
Toluol	0.5 ,,	
Xylol	0.7 ,,	
Pseudocumol	0.8 ,,	

The olfactometrical coefficients may readily be computed from them. They are for benzol 3.3; for toluol 2.0; for xylol 1,4 and for pseudocumol 1.3.

These liminal values vary distinctly as the series advances. Each

term has its peculiar odour, which enables us to tell the one from the other by smelling. The odours of benzol and toluol, however, are somewhat alike. Both are empyreumatic, that of toluol is the stronger of the two. Xylol, on the other hand, has lost the empyreumatic character almost entirely, and exhibits an aromatic quality. This quality is more obvious still in pseudocumol, so that in this respect it bears some resemblance to xylol. It seems to me that difference between xylol and pseudocumol is greater than that between benzol and xylol. Finally durol follows with an exclusively aromatic, phenol-like odour.

The Combination-test.

I feel convinced that a combination of the terms of the methyl-benzol series, without perceptible antagonism though weakening each other, may produce mixed smells, forming unmistakably a new unitary smell, though we still may trace in it the empyreumatic, respectively the aromatic quality of the component parts. It is rather

Combination	Cylinder-length	Sensation
Benzol-toluol	0.30 and 0.50 cm.	toluol-like
„ „	0.15 „ 0.25 „	„
„ „	0.07 „ 0.12 „	(none)
Benzol-xylol	0.15 „ 0.35 „	faintly benzol-xylol-like
„ „	0.07 „ 0.17 „	(none)
Benzol-Pseudocumol	0.20 „ 0.60 „	distinctly pseudocumol-like
„ „	0.15 „ 0.40 „	weak, doubtful odour
Toluol-xylol	0.40 „ 0.50 „	xylol-like
„ „	0.25 „ 0.35 „	„
„ „	0.15 „ 0.25 „	(none)
Toluol-Pseudocumol	0.35 „ 0.60 „	distinctly pseudocumol-like
„ „	0.25 „ 0.40 „	„ „
„ „	0.15 „ 0.30 „	(none)
Xylol-Pseudocumol	0.50 „ 0.60 „	distinctly pseudocumol-like
„ „	0.45 „ 0.50 „	weak mixture of pseudo-cumol and xylol
„ „	0.35 „ 0.40 „	(none)

immaterial whether the new sensation is looked upon as a mixed sensation or as a novel, individual one. Psychologically it seems to me e.g. that a combination of gaseous benzol and gaseous xylol yields one simple, unanalysable scent, though it contains an empyreumatic as well as an aromatic component.

From these experiments it follows in the first place, that the combination of two odours, belonging to an homologous series, yields a smell-sensation even when each separate odour is subliminal. Distinct smell-sensations were generally obtained by me with two half stimulus-limina consequently by adding two half liminal values. Here then we have to do with a summation-smell. Two subliminal stimuli, belonging to the same homologous series are added and build up together a smell-sensation. This phenomenon may be looked upon as an analogue to summation-actions occurring in another field in physiology. The present writer e.g. observed some time ago, that some rest nitrogen-compounds of various chemical composition exert a distinct influence upon the heart and the blood-pressure through their analogous physiological action, even when injected in such small quantities that of themselves they are inactive [1]).

The results of our combination-tests were to the following effect:

Combination	Cylinder-length	Sensation
Benzol-toluol-xylol	0.15—0.25—0.35 cm.	distinctly xylol-like
„ „ „	0.07—0.12—0.17 „	(none)
Benzol-toluol-pseudocumol	0.15—0.25—0.40 „	distinctly pseudocumol-like
„ „ „	0.07—0.12—0.20 „	doubtful, indistinct
Toluol-xylol-pseudocumol	0.35—0.45—0.60 „	distinctly pseudocumol-xylol-like
„ „ „	0.25—0.35—0.40 „	faintly pseudocumol-like
„ „ „	0.20—0.45—0.50 „	„ „

These combinations also substantiate our previous statement. In my judgment stimuli smaller than $^1/_2$ olfact do not build up a clear sensation.

Lastly we subjoin some combination-tests with four smell-stimuli: (See following table p. 950).

Also with these combinations every sensation is unitary. Still, in the first three groups the xylol-pseudocumol-scent supersedes. Sub-

[1]) E. L. Backman. Thesis. Upsala 1917.

Combination	Cylinder-length	Sensation
Benzol-toluol-xylol-pseudocumol	1.80—3.00—4.20—4.80 cm.	Mixed scent of benzol-toluol and xylol-pseudocumol. The latter superseding.
Benzol-toluol-xylol-pseudocumol	1.20—2.00—2.80—3.20 cm.	Mixed scent of benzol-toluol and xylol-pseudocumol. The latter superseding.
Benzol-toluol-xylol-pseudocumol	0.15—0.25—0.35 -0.40 cm.	Mixed scent of benzol-toluol and pseudocumol. The latter superseding.
Benzol-toluol-xylol-pseudocumol	0.07—0.12—0.17—0.20 cm.	(none).

liminal stimuli, when combined, build up an accumulative sensation here also. We conclude therefore: *The combination of two or more subliminal quantities of substances of an homologous series gives rise to a distinct accumulative odour.*

It is very difficult to say whether a similar summation occurs also with superliminal quantities, though to me it does not seem improbable.

The Compensation tests.

Initially one of the olfactometrical cylinders of the double olfactometer was moved out a little to obtain a stimulus of 6 olfacts. Subsequently a small amount, followed by a larger one, of another substance was added and the smell-sensation was observed. The determinations were made at intervals of various lengths and were repeated several times on the same and on successive days. In the interval between two tests the cylinders were pushed hard up against the screen to obviate excessive volatilization or to balance the diffusion-difference within the cylinder where, otherwise, the intensity of the upper layers of the odorous substance would be reduced. We still wish to call attention to the fact, that the results obtained one day were invariably found back on the following day.

Generally speaking we found that by keeping the amount of one substance constant, and allowing the other to increase, also the smell-sensation passes gradually from one odour into the other, but that there will always be a field in which the two odours weaken, nay even cancel each other. On the whole, therefore, complete compensation of the sensations is obtained by mixing carefully apportioned quantities of odorous substances.

Cylinderlengths	Sensation
1.8 cm. Benzol + 2.3 cm. Toluol	benzol-like
1.8 „ „ + 2.4 „ „	faint, indistinct odour
1.8 „ „ + 2.5 „ „	„ „ „
1.8 „ „ + 2.6 „ „	toluol-like
0.9 „ „ + 0.9 „ „	benzol-like
0.9 „ „ + 1.0 „ „	„
0.9 „ „ + 1.1 „ „	faint, indistinct odour
0.9 „ „ + 1.2 „ „	„ „ „
0.9 „ „ + 1.3 „ „	„ „ „
0.9 „ „ + 1.4 „ „	toluol-like
3.6 „ „ + 4.7 „ „	benzol-like
3.6 „ „ + 4.8 „ „	faint, indistinct odour
3.6 „ „ + 4.9 „ „	„ „ „
3.6 „ „ + 5.0 „ „	toluol-like
1.8 „ „ + 3.7 „ Xylol	benzol-like
1.8 „ „ + 3.8 „ „	(none)
1.8 „ „ + 3.9 „ „	(none)
1.8 „ „ + 4.0 „ „	(none)
1.8 „ „ + 4.1 „ „	xylol-like
0.9 „ „ + 1.5 „ „	benzol-like
0.9 „ „ + 1.6 „ „	faint, doubtful odour
0.9 „ „ + 1.7 „ „	(none)
0.9 „ „ + 1.8 „ „	(none)
0.9 „ „ + 1.9 „ „	faint, doubtful odour
0.9 „ „ + 2.0 „ „	xylol-like
3.6 „ „ + 7.7 „ Toluol	benzol-like
3.6 „ „ + 7.8 „ „	faint, doubtful odour
3.6 „ „ + 7.9 „ „	(none)
3.6 „ „ + 8.0 „ „	(none)
3.6 „ „ + 8.1 „ „	(none)
3.6 „ „ + 8.2 „ „	faint, doubtful odour
3.6 „ „ + 8.3 „ „	xylol-like

Cylinderlengths	Sensation
1.8 cm. Benzol + 1.5 cm. Pseudocumol	benzol-like
1.8 „ „ + 1.6 „ „	(none)
1.8 „ „ + 1.7 „ „	(none)
1.8 „ „ + 1.8 „ „	faint, doubtful smell
1.8 „ „ + 1.9 „ „	pseudocumol-like
0.9 „ „ + 0.6 „ „	benzol-like
0.9 „ „ + 0.7 „ „	(none)
0.9 „ „ + 0.8 „ „	(none)
0.9 „ „ + 0.9 „ „	pseudocumol-like
3.6 „ „ + 3.1 „ „	benzol-like
3.6 „ „ + 3.2 „ „	faint, doubtful smell
3.6 „ „ + 3.3 „ „	(none)
3.6 „ „ + 3.4 „ „	(none)
3.6 „ „ + 3.5 „ „	pseudocumol-like
3.0 „ Toluol + 1.9 „ Xylol	toluol-like
3.0 „ „ + 2.0 „ „	faint, doubtful smell
3.0 „ „ + 2.1 „ „	(none)
3.0 „ „ + 2.2 „ „	(none)
3.0 „ „ + 2.3 „ „	(none)
3.0 „ „ + 2.4 „ „	xylol-like
1.5 „ „ + 0.8 „ „	toluol-like
1.5 „ „ + 0.9 „ „	faint, doubtful smell
1.5 „ „ + 1.0 „ „	„ „ „
1.5 „ „ + 1.1 „ „	(none)
1.5 „ „ + 1.2 „ „	(none)
1.5 „ „ + 1.3 „ „	faint, doubtful smell
1.5 „ „ + 1.4 „ „	xylol-like
6.0 „ „ + 4.3 „ „	toluol-like
6.0 „ „ + 4.4 „ „	faint, doubtful smell
6.0 „ „ + 4.5 „ „	(none)
6.0 „ „ + 4.6 „ „	(none)
6.0 „ „ + 4.7 „ „	faint, doubtful smell

Cylinderlengths					Sensation
6.0 cm.	Toluol	+ 4.8 cm.	Xylol		xylol-like
3.0 „	„	+ 1.9 „	Pseudocumol		toluol-like
3.0 „	„	+ 2.0 „	„		faint, doubtful smell
3.0 „	„	+ 2.1 „	„		(none)
3.0 „	„	+ 2.2 „	„		(none)
3.0 „	„	+ 2.3 „	„		faint, doubtful smell
3.0 „	„	+ 2.4 „	„		pseudocumol-like
1.5 „	„	+ 0.9 „	„		toluol-like
1.5 „	„	+ 1.0 „	„		(none)
1.5 „	„	+ 1.1 „	„		(none)
1.5 „	„	+ 1.2 „	„		(none)
1.5 „	„	+ 1.3 „	„		pseudocumol-like
6.0 „	„	+ 4.1 „	„		toluol-like
6.0 „	„	+ 4.2 „	„		faint, indistinct smell
6.0 „	„	+ 4.3 „	„		(none)
6.0 „	„	+ 4.4 „	„		(none)
6.0 „	„	+ 4.5 „	„		pseudocumol-like
4.2 „	Xylol	+ 2.8 „	„		xylol-like
4.2 „	„	+ 2.9 „	„		faint, indistinct smell
4.2 „	„	+ 3.0 „	„		(none)
4.2 „	„	+ 3.1 „	„		(none)
4.2 „	„	+ 3.2 „	„		(none)
4.2 „	„	+ 3.3 „	„		(none)
4.2 „	„	+ 3.4 „	„		faint, doubtful smell
4.2 „	„	+ 3.5 „	„		pseudocumol-like
7.0 „	„	+ 5.0 „	„		xylol-like
7.0 „	„	+ 5.1 „	„		(none)
7.0 „	„	+ 5.2 „	„		(none)
7.0 „	„	+ 5.3 „	„		(none)
7.0 „	„	+ 5.4 „	„		(none)
7.0 „	„	+ 5.5 „	„		faint, doubtful smell
7.0 „	„	+ 5.6 „	„		pseudocumol-like

The compensation is indistinct only for benzol and toluol. We also ascertained in every test that in the neighbourhood of the compensation-point smell-sensation grows weaker.

We invariably found the ratios of the cylinderlengths of two antagonistic substances to be the same for a particular compensation-pair. They appear again when reducing the cylinderlengths to olfaction-values.

Number of olfacts				Sensation
Benzol	Toluol	Xylol	Pseudocumol	
3	2.4			(0)
6	4.9			(0)
12	9.7			(0)
3		2.5		0
6		5.6		0
12		11.4		0
3			1.0	0
6			2.0	0
12			4.2	0
	3	1.7		0
	6	3.2		0
	12	6.5		0
	3		1.4	0
	6		2.7	0
	12		5.5	0
		6	3.9	0
		10	6.6	0

This investigation, then, confirms the rule previously found by ZWAARDEMAKER [1]) for other compensation-pairs, viz. when a olfacts

[1]) H. ZWAARDEMAKER, die Physiologie des Geruchs, Leipzig 1895 S. 194. Cf. ZWAARDEMAKER the restriction to the domain of cardinal values in Tig. Hdb d. Physiol. meth. Bd. III 1. p. 89. Beyond the domain of the cardinal values the log. of a and b will have to be multiplied.

of one odorous substance are neutralized by b olfacts of another, $n \times a$ and $n \times b$ olfacts will similarly neutralize each other. What strikes us as novel and remarkable, is that a typical compensation was found with odorous substances of one and the same homologous series.

Complete compensation may of course also be obtained among four homologues. We subjoin the results of an experiment with the quadruple olfactometer

Number of olfacts				Sensation
Benzol	Xylol	Toluol	Pseudocumol	
12	11.4	12	5.5	(none)
12	11.4	10	5.5	pseudocumol-like
12	8.6	12	5.5	benzol-like
12	13.6	12	5.5	xylol-like
12	0	12	0	benzol-toluol-like

Another similar compensation is e.g. benzol 12, pseudocumol 4.2, toluol 12 and xylol 6.5 olfacts. This combination also gives complete compensation. Likewise toluol and pseudocumol can compensate xylol alone, e.g. 14 olfacts of toluol and 3.9 olfacts of pseudocumol with 13.5 (7.4 + 6.0) olfacts of xylol.

SUMMARY.

1. The liminal stimulus of the odorous substances of the methylbenzol series exhibits for the first four terms a fairly proportional decrease with increasing methylation. Consequently the liminal smells intensify as the series advances. Moreover they pass from a marked empyreuma (benzol-toluol) to a predominating aroma (xylol-pseudocumol) until ultimately a phenol-like odour (durol) comes to the front.

Meanwhile the smell-intensity lessens, so that a prolonged methylation may perhaps give rise to inodorous compounds.

2. The rate at which the odour is spread by diffusion is nearly the same for the four homologues examined.

3. The electric charge produced by spraying an equimolecular solution of the substances augments slowly at first, afterwards more rapidly as the series advances.

4. The adsorption of the substances examined to electrically charged metallic plates is next to none.

5. The four terms examined may evoke unitary mixed sensations, without a trace of antagonism.

6. Combinations of two or more subliminal stimuli yield (anyhow in the proportions of our tests) a distinct accumulative effect. It seems, however, that to obtain this result no less than $^1/_4$ olfact should be taken.

7. The combination of two or more fairly strong stimuli of the homologous series examined by us effectuates with careful apportionment a complete compensation of the mixed odours to the zero-point of the sensitive scale. This takes place without antagonism. Only when the odorous substances are closely allied, as in the case of benzol and toluol, the compensation is less complete.