Physiology. — *"Influence of the seasons on respiratory exchange during rest and during muscular exercise"*. By Dr. C. J. C. van Hoogenhuyze and Dr. J. Nieuwenhuyse.

(Communicated by Prof. C. Eijkman in the meeting of October 26, 1912).

The primary object of our inquiry has been to find out, whether muscular exercise increases the metabolism in man as much in the cold as in the warm season.

We have taken the consumption of oxygen as the index of the metabolism.

Since it is still a matter of controversy, whether the seasons influence metabolism even during rest, we have thought fit to determine also the absorption of oxygen during rest in the same two persons, who were subjected to the muscular test. Besides, the gas-exchange has also been examined with two other subjects only during rest.

A. *Respiratory Gas-exchange during rest.*

In 1859 E. Smith [1]) presented to the Royal Society of London a series of observations upon the influence of different factors (i. a. the seasons) on the gas-exchange in man during rest. The amount of oxygen consumed was not determined, only that of carbon dioxide given off. If we are to take the latter as a quantitative index of the metabolism, Smith's experiments would prove that it is more intense in the cold months and less so in the warm season.

Eijkman[2]) made similar experiments in 1897 with improved means, and moreover measured the quantities of oxygen. As known, the latter afford a more reliable index of the intensity of the metabolism. He found no difference for the different seasons.

His opinion that the metabolism is the same in warm and in cold seasons is also corroborated by his previous investigations [3]) made in the East-Indies, from which it appeared that the amount of metabolism of man in the tropics agrees with that of people in our parts.

1) Philosophical Transactions of the Royal Society of London 1859 p. 681.

2) C. Eijkman. Over den invloed van het jaargetijde op de menschelijke stofwisseling. Verslagen van de Koninklijke Akademie van Wetenschappen te A'dam, 8 Dec. 1897.

3) C. Eijkman. Beitrag zur Kenntniss des Stoffwechsels der Tropenbewohner. Virchow's Archiv. Band 133. 1893, p. 105.

Idem. Ueber den Gaswechsel der Tropenbewohner, Pflüger's Archiv. Band 64, 1896, p. 57.

Shortly before we had brought our experiments to a close, LINDHARD [1]) published an article, in which he reports the fluctuations of respiratory exchange in the different seasons, which according to him run parallel to the intensity of the sunlight.

It seems to us however, that his values of the oxygen intake do not differ sufficiently and are too inconstant to warrant such a conclusion.

For our determinations we used ZUNTZ and GEPPERT'S [2]) method. The subject, whose nose is shut off by a spring-clip, breathes through a mouth-piece, corresponding by means of a T-shaped tube with two very mobile gut-valves, one of which transmits only the air taken in, the other only the air which is exhaled. The latter passes, without encountering any resistance worth mentioning, through a slightly aspirating gasometer, a constant fraction of the expired air being continually separated for gas-analysis by means of a special apparatus. Furthermore a supple pig's bladder had been inserted between the valves and the gasometer. This highly facilitated expiration, as was apparent from the working-experiments to be discussed later on.

Outside air was supplied through a short and wide india-rubber tube, connected with the valves. The room which faced the North, was constantly well ventilated through the open windows.

We experimented every time under similar circumstances, i. e. the experiments were made in the morning, always at the same hour, and with the same interval after breakfast.

The breakfast varied for the several subjects, but for each individually it was the same. For a quarter of an hour before and during the experiment, the subject reclined in an easy chair, resting quietly. The temperature of the room was taken, the readings of the barometer and the sort of weather (misty, sunny, frosty etc.) were noted down.

Likewise the respiration, the number of liters of air exhaled, and the time (in seconds) were recorded on a kymographion (Fig. 1).

The time the experiment took us, was also registered by a timekeeper. Furtheron the relative moisture in the room was measured too as well as the temperature and the degree of moisture under the clothes.

Our subjects were four adults, all of them employed every day

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1) J. LINDHARD. Seasonal periodicity in respiration.
Skandinav. Archiv. f. Physiologie XXVI p. 221.

2) MAGNUS-LEVY. Ueber die Grösze des respiratorischen Gaswechsels u. s. w.
Pflüger's Archiv. f. die ges. Physiologie. Bd 55. 1894, p. 9.

at the hygienic laboratory at Utrecht. Their body-weights were widely different and did not change much with the same individual.

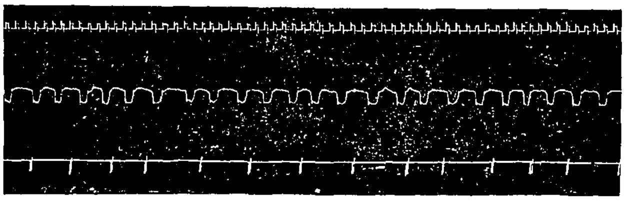

Fig. 1.

The lowest temperature, at which we worked was 3°, the highest 30°.

The experiments were made in May, June, July, September, October, November 1911 and in January, February, and July 1912.

There was only a small difference in the summer- and the winter-attire. No overcoat was ever put on in cold weather nor was any article of attire taken off in the summer. As serious errors would originate in case the subject should shiver, this was a point of careful observation.

In looking over our results, in the first place with regard to the amount of oxygen, we notice rather considerable fluctuations with the same subject under apparently similar circumstances, which is in accordance with the experience of other workers.

Benedict [1]), for instance, found in experiments with the same subject under equal circumstances the following oxygen-consumption: 194—213—169, showing as great a difference as 26°/₀.

We also found with *N.* on 15—7—'12, at 30°, 765,5 mm. barometric pressure, relative moisture of 52°/₀, the value 256,8, and on 16—7—'12, at 30° and 765,5 mm. barometric pressure, relative moisture of 50°/₀, the value 292. This yields a difference of rather more than 13°/₀.

It is obvious, therefore, that if we wish to demonstrate seasonal influence, an extended series of experiments is required, and furthermore, that only striking differences should be attended to. If we take the average of the results at a temperature below 13° (the months of Nov. Dec. Jan. Feb.) and of those above 13° (the other months) we note:

[1]) Benedict. The metabolism and energy transformation of healthy man during rest. (Carnegie Institution of Washington. Publication no. 126, 1910, p. 107.)

		below 13°			above 13°
with *vH.*	(5 exp.)	281.8 c. c. per min.	(18 exp.)		269.2
„ *N.*	8 „	252.4 „ „ „	21 „		256
„ *E.*	6 „	290.8 „ „ „	9 „		297.4
„ *K.*	4 „	207.7 „ „ „	12 „		197.7

The average of
4 subjects (23 exp.) 1032.7 : 4 = 258.2 and (60 exp.) 1020.3 : 4 = 255.1.

In considering the results obtained with each individual separately we notice differences in one way or another, comparatively small though they may be.

In connection with what has been said above we believe that no great value should be set upon these differences.

Taking the averages of all the subjects, we find fairly corresponding values, viz. 258.2 in the cold and 255.1 in the warm season, so that we may conclude, that the season has no influence upon the metabolism in a state of repose.

It appears then, that our results agree with those of EIJKMAN [1]) who got his averages in like manner, finding 253.8 in the winter and 253.3 in the summer.

Without tabulating our results at large we subjoin a somewhat more detailed report about them :

I *V. H.* Body-weight 87½ Kilos (without clothing) Height 1.84 m.

Averages of results of all experiments (23): Amount of O_2-consumption and CO_2-production per minute expressed in c.c. reduced to 0° and 760 mm. barometric pressure.

CO_2	O_2	CO_2/O_2
225,2	271,1	0,830
minimum 185	min. 239,5 = 11 % below the average.	
maximum 264,6	max. 322,5 = 19 % above „ „	

The average O_2-consumption in 5 experiments at 4½—12½° C. amounted to
281,8
min. 259,9
max. 322,5

The O_2-consumption in 18 experiments at temperatures of from 14½—30° C. averaged
269,2
min. 239,5
max 294,2

At the lowest temperature (4½° C.) we found 274,1, at 7½° C. 322,5.
„ „ highest temperatures (30 ° C.) „ „ 291,7 and 294,2.

II. *N.* Body-weight 70½ Kilos (without clothing) Height 1,80 m.

Averages of results of all experiments (29):

CO_2	O_2	CO_2/O_2
230	255	0,900
min. 191,7	min. 222,2 = 13 % below the average.	
max. 267	max. 292 = 14 % above „ „	

1) C. EIJKMAN. Koninkl. Akademie v. Wetenschappen 8 Dec. 1897.

The average O_2-consumption in 8 experiments at temperatures of 4—13° C. amounted to

252,4
min. 230,5
max. 285,1

The O_2-consumption in 21 experiments at temperatures of 14—30° C. averaged

256
min. 222,2
max. 292

At the lowest temperatures (4 °) we found 260,7 and 285,1.
„ „ highest „ (30°) „ „ 256,8 292 and 277,7.

III *E.* Body-weight 83,3 Kilos (without clothing) Height 1,82 m.
Averages of results of all experiments (15)

CO_2	O_2	O_2/O_2
258,6	294,7	,801
min. 219,6	min. 250,8 = 15 % below the average	
max. 309,7	max. 330,1 = 12 % above „ „	

The average O_2-consumption in 6 experiments at temperatures of 8—13° C. amounted to

290,8
min. 272,6
max. 330,1

The average O_2-consumption in 9 experiments at temperatures of 14—26° C. amounted to

297,4
min. 279,9
max. 328.4

IV. *K.* Body-weight 58 Kilos (without clothing) Height 1.75 m.
Averages of results of all experiments (16)

CO_2	O_2	CO_2/O_2
175,1	200,2	0,874
min. 152	min. 172 = 14 % below the average	
max. 205,9	max. 238,6 = 19 % above „ „	

The average O_2-consumption in 4 experiments at temperatures of 3—12½° C. amounted to

207,7
min. 177,7
max. 228,6

The O_2-consumption in 12 experiments at temperatures of 14—30° C. averaged:

197,7
min. 172,0
max. 238,6

Our endeavours to detect any influence of the seasons on the carbon-dioxide elimination, the tidal air, and the number of respirations per minute proved as fruitless as they had been in ascertaining such influence on the oxygen-consumption.

B. *Respiratory Gas-exchange during muscular exercise.*

Little has been written as yet about the influence of muscular work on the respiratory exchange in the several seasons.

E. SMITH reported in his publication, of which mention has already been made, that equal muscular work has a greater influence on the respiratory exchange in winter than in summer; his experimentation, however, does not, in our opinion, vouch for this conclusion.

Our experiments were made in the months of March, April, May, June, and July 1912.

We proceeded as follows. The experimentation took place in the afternoon, at the same hour, shortly before dinner, in order to give scope to the presumable influence of close heat. We were sitting on a bicycle without wheels, placed on a stand. A rotatory disk had been fixed at the place of the large chain-wheel. Round it a steel brake-band could be tightened or slackened to render the work more severe or lighter (Fig. 2).

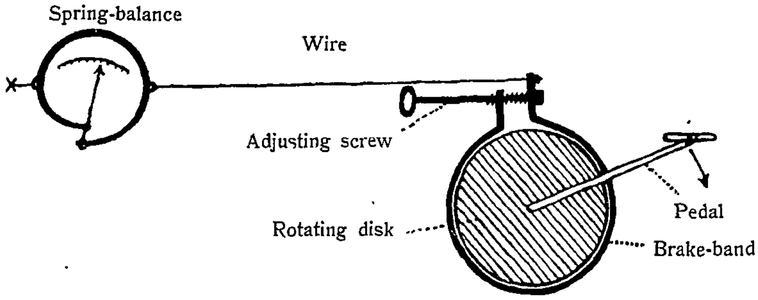

Fig. 2.

The upper part of the band was connected with a spring-balance by means of a long wire. When the adjusting screw was tightened the friction increased and the band was taken along by the disk, while the pedalling continued, which caused the springbalance to register a higher figure. The increase, however, was not such as to alter the static moment materially. Both the bracket-spindle of the bicycle and the rim of the disk were continually being oiled during the experiment.

The pedalling rate was regulated by a metronome, ticking 133 times per minute.

Before the subjects, both skilled cyclists, started pedalling, a determination was made, while they were quietly seated on the bicycle; which involved only a very light static muscular activity. In the subsequent period of the experiment the subject was pedalling for a quarter of an hour, while breathing freely and after this for five minutes, while breathing through the valves. Only then the estimation was performed, while the subject went on pedalling; we then could reasonably presume that a condition of equilibrium between internal and external gas-exchange had been established.

The breathing through the valves for the space of five minutes previous to the estimation, served to prevent a somewhat irregular respiration that might possibly arise in the transition from free breathing to respiring through the valves. In the interval the temperature in the gasometer attained its new equilibrium.

Throughout the whole experiment an assistant had to watch the springbalance, which was to point to the same mark. In case of a deviation, the band was at once slackened or tightened during the pedalling, which did not cause any disturbance.

The work done was calculated by multiplying the circumference of the disk, i. e. the distance covered after one rotation, by the weight indicated on the springbalance, by the number of rotations per time-unit and by a correcting factor [1]). This showed an amount of labour of 22800 K.G M. per hour.

The exertion required for the work, was not such as to exhaust the subjects. Still, at the finish of the experiment they felt tired as if they had been cycling a long distance.

Our results are the following:

I. *V. H.* { sitting quietly (*a*):
pedalling (*b*).

Averages of all the experiments (12) made in March, April, May, June, July 1912, lowest temperature 12°, highest temperature 30°:

	CO_2 per min.	O_2	$\frac{CO_2}{O_2}$
a	280,8	min. 299 max. 386,8 330,4	0.850
b	868,4	1001,5 min. 781,2 max. 1448	0,8671

The average of 8 experiments below 21 1/2°

	CO_2	O_2	$\frac{CO_2}{O_2}$
a	273,3	min. 299 max. 358,8 323,5	0,8448
b	746,2	863,4 min. 781,2 max. 988,5	0,8643

The average of 4 experiments above 21 1/2°.

	CO_2	O_2	$\frac{CO_2}{O_2}$
a	295,9	min. 322.1 max. 386.8 344,5	0,8589
b	1113,1	1277,7 min. 1052 max. 1448	0,8712

Increase set in after 11—6—'12 (above 21 1/2°).

[1]) The correcting factor is the quotient of the lever on which the wire of the springbalance is fixed and the radius of the disk.

II. *N.* sitting quietly *a*: pedalling *b*:

Averages of all the experiments (14) made in the same months; lowest temperature 12°, highest 31°:

	CO_2	O_2	$\frac{CO_2}{O_2}$
a	212,5	min. 229 max 314,9 265,4	0,8346
b	819,6	895,6 min. 652,1 max. 1091	0,9152

The average of 8 experiments below 20½°:

	CO_2	O_2	$\frac{CO_2}{O_2}$
a	214,6	min. 229,6 max. 314,9 268,8	0,7984
b	717,9	791 min. 652,1 max. 922,7	0,9076

The average of 6 experiments above 20½°:

	CO_2	O_2	$\frac{CO_2}{O_2}$
a	209,6	min. 229 max. 288,9 260,8	0,8037
b	955,2	1034,9 min. 977,2 max. 1091	0,923

Increase set in above 20½°, after 13—5—'12.

Also in this series of investigations the individual fluctuations were rather considerable.

We see that for either subject the average oxygen-intake is higher when sitting quietly on the bicycle than when lying in a chair, viz.

V. H.	(lying)	average Oxygen-intake	271.1 cc.
	(sitting)	„ „	330.4 „
N.	(lying)	„ „	255 „
	(sitting)	„ „	265.4 „

We also observe that the average value of the sitting-experiments at more than 21½° with *V. H.* is a little higher than that of the experiments below 21½° viz.

the first value: 344.5, the second 322.5.

Again, that for *N* there is no such difference between the two periods. On the contrary with him rather the reverse takes place, the first value being 260.8, the second 268.8. However, this difference is too small to be taken into account.

While pedalling *V. H.* shows an essential increase of oxygen-intake, when the temperature rises beyond 21°, at the beginning of June. With *N* the increase is not so great, but it starts a month earlier, when the temperature rises beyond 20° viz.

with *V. N.* from average 863.4 to 1277.7, nearly 48 %
„ *N.* „ „ 791 „ 1034.2. „ 31 %

The lowest value of the warm period in *H*'s experiments (1052) is distinctly higher than the highest of the cold period (988.5).

Likewise with *N* viz. the one 977.2, the other 922.7.

On the days of the higher values either subject felt, as if the muscular work required a greater physical exertion than on other days, though they were both in good health and followed their daily routine.

In noting the average increase of the absorption of oxygen, resulting from the pedalling, we find:

with *V. H.* below $20\frac{1}{2}°$ 863—323.5 = 441.5
above $21\frac{1}{2}°$ 1277—244.5 = 933.2,

a difference of 491.7 (nearly 112 %).

With *N* below $21\frac{1}{2}°$ 791 —268.8 = 522.2
above $20\frac{1}{2}°$ 1034.9—260.8 = 774.1,

a difference of 251.9 (rather more than 48 %).

The numbers expressing the carbon-dioxide output are running parallel to those indicating the oxygen-intake. This tallies with the approximate accordance of the respiratory quotients of the experiments made at a temperature higher than $20^1/_2°$ and $21^1/_2°$, with those of the other experiments.

In the case of *N* the temperature under the clothes, on the cessation of the pedalling was 35—$35^1/_2°$ C., the relative moisture 65—90 %, throughout the whole period above $20\frac{1}{2}°$. In the period below $20\frac{1}{2}°$ the former varied from 30° — 34°, the latter from 30%—47%.

With *V. H.* those values were:

in the period above $21\frac{1}{2}°$: 34— $35^1/_2°$
90—100%

" " " below $21\frac{1}{2}°$: 30— $34^1/_2$
40— 75%

As regards the respirations per minute and the tidal air at the end of the pedalling experiments we find:

		number of respir. per min.	Tidal air
average with *V. H.*	below $21\frac{1}{2}°$	17.2	1009.6
	above $21\frac{1}{2}°$	16.2	1444
with *N.*	below $20\frac{1}{2}°$	20.1	840.7
	above $20\frac{1}{2}°$	21.7	1003.5

We see, therefore, that the number of respirations per minute remains fairly constant, whereas in the warm season the tidal air is considerably augmented, viz.

with *V. H.* an increase of more than 34%
„ *N.* „ „ „ „ „ 19%

We have previously remarked, that the increased respiratory exchange at a higher temperature cannot be attributed to this, seeing that the determination had not been made, until an equilibrium had presumably been established between internal and external gas-exchange. Indeed, the O_2-consumption and the CO_2-elimination increased more considerably than the tidal air.

Our experimental evidence seems to show that muscular work at a high temperature is less economical than at a low temperature, and also that this difference is more marked with one subject than with another.

The increase of gas-exchange parallel to the rise of temperature was not gradual, but sudden at 21°—22°.

Physiology. — *"The influence of the reaction upon the action of ptyalin"*. By Dr. W. E. RINGER and H. v. TRIGT.

(Communicated by Prof. C. A. PEKELHARING in the meeting of November 30, 1912).

One of us (v. TR.) has for some time been studying the effect of diet on the action of the diastatic enzyme of the saliva, to which the name ptyalin has been applied. The results of other researchers into this subject are to some extent conflicting with each other [1]). Nor do VAN TRIGT's experiments positively demonstrate an influence of diet. Though, taking one with another, they seemed to point to an influence, occasionally there appeared striking deviations without our being able to fix upon the cause, so that we did not know what to make of the results.

This experimentation was conducted as follows: saliva was added to amylum solutions and after some time the reducing power of the solutions was determined. This method involves the risk of fluctuations in the reaction of the fluids, e.g. such as are brought about by the flask-wall or by carbon dioxide from the air, since in approximately neutral fluids without regulating-mixtures the reaction may be considerably shifted by a trifling disturbance. This would account for the striking deviations mentioned just now, recent researches having shown that slight modifications of the reaction markedly affect the activity of enzymes.

Now if, in prosecuting our experiments, due care being taken all

[1]) Cf. HAMMARSTEN's Lehrbuch der physiologischen Chemie.