who believe that the vowels are composed of tones that are necessarily harmonic. Neither can I see any connexion whatever between the harmonic theory of the vowels and the resonance theory of hearing. The last sentence of Prof. Scripture's letter leads me to suppose that he does. It would very greatly interest me to know what he thinks the connexion is.

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April 29.

On Approximate Integration.

IN vol. 105 of NATURE, 1920, several very interesting letters were published concerning approximate integration. It is to be noted that all the formulæ alluded to in these letters are founded on the analytical method which consists in replacing the integrand by a polynomial. It appears that one very good formula based on geometrical reasoning and discovered by Poncelet is not so well known in Great Britain as it is in France. It may interest readers of NATURE, therefore, to try this formula. The general form is

$$\int_a^b y\,dx \approx h\left[2P + \frac{E_1 - E_2}{4}\right], \quad . \quad . \quad (1)$$

the interval (a, b) being divided into $2n$ sub-intervals each equal to h, P being the sum of those of the ordinates $y_1, \ldots y_{2n+1}$ the indices of which are even, E_1 being the sum of the extreme ordinates $y_1 + y_{2n+1}$, and E_2 being the sum of the ordinates next to them, $y_2 + y_{2n}$. The most remarkable feature of this formula is that, when the graph of y is everywhere concave to the x-axis (or everywhere convex), it gives an upper bound of the error, extremely simple and *not* necessitating the knowledge of the *derivatives* of y, namely: [1]

$$\left(\int_a^b y\,dx - h\left[2P + \frac{E_1 - E_2}{4}\right]\right) < h\left(\frac{E_1 - E_2}{4}\right).$$

For the case where $h = \frac{1}{10}(b - a)$, $a = 0$, $b = 1$, Poncelet's formula reduces to

$$\int_0^1 y\,dx \approx \tfrac{1}{10}\left\{2[y(0{\cdot}1) + y(0{\cdot}3) + y(0{\cdot}5) + y(0{\cdot}7) + y(0{\cdot}9)] - \tfrac{1}{4}[\overline{y(0) - y(0{\cdot}1)} - \overline{y(0{\cdot}9) - y(1)}]\right\}.$$

This seven-ordinate formula may be compared with Simpson's seven-ordinate rule. Taking the numerical examples of Mr. Dufton, the errors of these two seven-ordinate rules are shown in the following table:

Errors on the value of $\int_0^1 f(x)dx$ computed by the seven-ordinate when $f(x) =$									
Simpson's rule	0·0112	0·0079	0·011	0·0000	0·0000	0·0001	0·0000	0·0000	0·0045
Poncelet's rule	0·0044	0·0032	0·004	0·0003	0·0010	0·0004	0·0001	0·0003	0·0037
	$\sqrt{x - x^2}$	$\sqrt{1 - x^2}$	$\sqrt{4x - x^2}$	$\log(1+x)$	e^x	$1/(1+x)$	$1/(2+x)$	$\sin x$	$1/(1+25x^2)$

It will be noted that the abscissæ involved in the seven-ordinate Simpson's rule are 0, $\frac{1}{6}$, $\frac{2}{6}$, . . . and in the seven-ordinate Poncelet rule they are 0, 0·1, 0·3, 0·5, 0·7, 0·9, 1, so that the computation of the ordinates in Poncelet's rule will often be more easy.

On the other hand, it is important to note that *when the fourth derivative of y is known*, a very precise limitation of the error involved in Simpson's formula may be obtained, this error being $-h^4\frac{(b-a)}{180}y_c^{(IV)}$, with $a < c < b$, whatever be the number of ordinates.

Generally speaking, Simpson's rule is best adapted to the integration of mathematically defined functions; Poncelet's rule to empirically defined functions.

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[1] See de la Vallée-Poussin, "Cours d'analyse infinitésimale," t. i., third edition, 1914, p. 395.

The Migration of a Red Sea Crab through the Suez Canal.

THE Suez Canal was completed in 1869, and since that date it has been invaded from both ends by plants and animals. Some members of the Red Sea fauna have passed right through the Canal to spread into the Mediterranean, and some Mediterranean species have reached the Red Sea. Had periodic faunistic surveys of the Canal been made since the beginning, valuable information would have been obtained concerning the stages in the mixing of two entirely different faunas. Unfortunately this has not been done. To my knowledge there are only three published investigations of the Suez Canal fauna. The first, dated 1882 (C. Keller, "Die Fauna im Suez Kanal," Denkschriften der schweizerischen Gesellschaft für die gesamte Naturwissenschaften, Bd. 28), deals largely with the invertebrates; the second, in 1902 (J.-B. Tillier, "Le Canal de Suez et sa fauna ichthyologique," Mém. de la Soc. Zool. de France, t. 15, p. 279), concerns the fish alone; and the third, dated 1905 (L. Tillier et A. Bavay, "Les mollusques testacés du Canal de Suez," Bull. de la Soc. Zool. de France, t. 30, p. 170, and t. 32, p. 129), deals with the molluscs. It is proposed this year to repeat the earlier work in order to see what further immigration has taken place since then, and further to study the factors which permit and prevent migration.

I was last year able to fix the dates of the various stages in the migration northward through the Canal of a Red Sea crab, *Neptunus* (*Portunus*) *pelagicus*, and to trace the apparent limits of its present distribution along the Mediterranean coasts. This crab is fished for food in Egypt, so that when found in abundance at any place its presence is noted. My information regarding the dates of arrival of the crab from the south at various points along the Canal has been obtained from certain of the Canal Company's employés who happen to be keen fishermen. Naturally such evidence depends upon the memory of individuals, which might easily be mistaken, but I consider that all the dates recorded below are approximately accurate, since the evidence of more than one independent witness has agreed concerning them.

Neptunus pelagicus commenced to invade the Canal between 1889 and 1893 and reached Port Said in 1898. Keller (*loc. cit.*, p. 22) records that there was only one brachyuran in the Canal in 1882, "eine kleine Krabbe." This was evidently not Neptunus. Keller says that "kein einziger grösserer Kruster ist bisher auf der Wanderung beobachtet." In 1889 *Neptunus pelagicus* was unknown at the Signal Station at the southern end of the Little Bitter Lake, 29 kilometres from Suez, although to-day it is common there. In 1893, however, it had become numerous at Kabret, at the junction of the Little with the Great Bitter Lake, 42 km. from Suez. In the same year the crabs were observed for the first time at Toussoum, 75 km. from Suez. In 1898 they arrived at Port Said, 162 km. from Suez, and four years later were common in the port.

It is remarkable that the migration did not commence earlier than 1889, since anterior to that date *Neptunus pelagicus* was abundant in the Gulf of Suez. This late beginning of the invasion may be correlated with some physical change in the Canal, but the nature of this is at present unknown. The principal obstacle to crab migration may be the high salinity of the Bitter Lakes on the course of the Canal, but it is not known whether a change took place in this