ence limens for intermittent mechanical pulses, at pulse repetition rates of 1 to 320 cy/sec, by means of a phonograph cutting head in which the moving element was held between the thumb and one other finger. The moving element was fitted with a flat plate of 50 mm². Therefore, the total skin surface that was excited was 100 mm². Ten thresholds from each of five observers were obtained at each of ten frequencies between 1 and 320 cy/sec; electric pulse durations that were increased from 1.5 msec at 320 cy/sec to 7.5 msec at 1 cy/sec were used. The sensation level above the absolute threshold for feeling vibration was from 17 to 26 decibels.

Two electronic, rectangular pulse generators of variable frequency and pulse duration drove the mechanical stimulator. The observer felt the moving element of the vibrator on the skin of the finger tips of one hand and sampled the standard and comparison frequencies successively by a selector switch which he operated with the other hand. He also used his switch hand to control the frequency of the comparison stimulus by a linear multirevolution potentiometer. The experimenter set the comparison frequency away from the standard by a random amount, and the observer obtained equality judgments by the method of adjustment, alternately starting from frequencies above and below the standard. The discrepancy between the standard and the comparison frequencies was measured with an electronic counter, to an accuracy exceeding that of the generating equipment. The circuit that was required to produce the standard and comparison repetition rates and pulse durations is described elsewhere (7). The mechanical stimulator was mounted in a sound-absorbing box, and a masking noise was delivered to the observer through headphones.

Table 1. Difference limens for intermittent mechanical stimulation on the finger tips. Cutting head stimulator with 100 mm² contact area. Five observers.

Frequency (cy/sec) Standard	Frequency (cy/sec) Mean obtained	*AD* (Δf) (cy/sec)	$\Delta f/f$ from *AD*	Cumulative DL's (*jnds*)
1	0.99	0.02	0.02	35.71
2.5	2.50	0.06	0.02	70.80
5	5.01	0.20	0.04	89.93
10	10.13	0.45	0.04	106.52
20	19.68	0.76	0.04	126.36
40	39.98	1.18	0.03	151.68
80	80.21	3.90	0.05	167.04
160	162.21	12.96	0.08	173.22
240	228.25	13.89	0.06	178.98
320	325.02	24.43	0.08	180.62

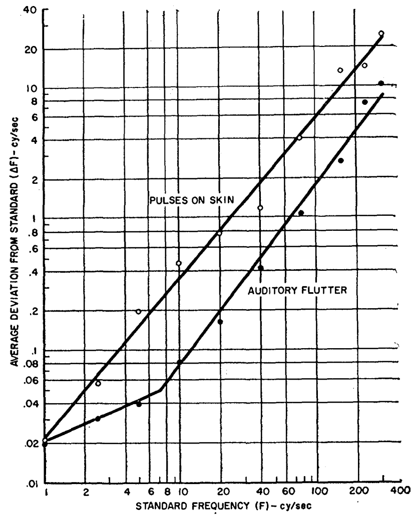

Fig. 1. The difference-limen function for discriminating rate. Upper curve: short pulses by the skin of the finger tip; log $\Delta f = (0.3410\text{-}2) + 1.2008 \log f$, for $f = 1$ to 320 cy/sec. Lower curve: intermittent white noise with a duty cycle of 0.5; visually fitted curve from 1 to 5 cy/sec; log $\Delta f = (0.5357\text{-}3) + 1.3479 \log f$, for $f = 5$ to 320 cy/sec.

The results for the rate discrimination of short pulses are shown in Table 1 and in the upper curve of Fig. 1. Column 2 of Table 1 shows the mean obtained frequency. By comparing these figures with those in column 1, it can be seen that the standard is matched, on the average, with an error of less than 12 cy/sec. Column 3 shows Δf as the average deviation (*AD*), computed with reference to the standard frequency (f). This rises monotonically with f. Column 4 gives the relative difference limens $\Delta f/f$, and column 5 shows the cumulative difference limens found by graphic integration of $1/\Delta f$, where Δf is the average deviation in column 3. The result is 180 just-noticeable differences (*jnd*) in the range of 1 to 320 cy/sec. The observed relationship between Δf and f is best expressed by the equation log $\Delta f = (0.3410\text{-}2) + 1.2008 \log f$ and, therefore, may be approximated by a parabola of the form $y = ax^b$.

Two other types of tactile stimulators were used to obtain similar results. These were a modified loud-speaker motor and a precision miniature vibration generator (8). Data were also obtained, by the method described, with contactors that covered 1 mm² and 20 mm² of skin area on a single finger tip. There was no indication that the size of the area stimulated made any difference in the difference limens for rate discrimination.

It is clear, of course, that no mechanical transducer of the type used here will faithfully follow the pulse-wave form of the electric input. At higher frequencies, the stimulus applied to the skin approaches a sine wave. Périlhou (9), and others, have measured Δf for sine waves. He found that $\Delta f/f$ varies with intensity between 0.02 and 0.40. The determination of accurate values of Δf with sine waves offers special difficulties, because frequency and intensity tend to be confounded in the matches. This appears not to be the case with pulses at low frequencies. We have found, therefore, that the linear relationship in Fig. 1 begins to break down after about 320 cy/sec, when the transducer no longer follows the rectangular input.

The lower curve in Fig. 1 shows our difference limens for flutter (2). The two curves have nearly the same slopes between 10 and 320 cy/sec; this suggests that the mechanism for rate discrimination is the same for the skin and the ear. Our values for frequency discrimination and those obtained by v. Békésy (5) with his dimensional model of the cochlea, in which he substitutes the skin of the arm for the basilar membrane, are in reasonably good agreement (see his Fig. 20). However, the skin has by no means the temporal resolving power of the ear at moderate sensation levels. In the frequency range of 1 and 320 cy/sec, the skin achieves less than 200 just-noticeable differences, whereas the ear produces more than 500.

G. H. Mowbray
J. W. Gebhard

Johns Hopkins University
Applied Physics Laboratory,
Silver Spring, Maryland

References and Notes

1. G. H. Mowbray and J. W. Gebhard, *Science* 121, 173 (1955); J. W. Gebhard, G. H. Mowbray, C. L. Byham, *Quart. J. Exptl. Psychol.* 7, 49 (1955).
2. G. H. Mowbray, J. W. Gebhard, C. L. Byham, *J. Acoust. Soc. Amer.* 28, 106 (1956).
3. J. W. Gebhard *et al.*, *J. Opt. Soc. Amer.* 46, 851 (1956).
4. This report was prepared under contract NOrd 7386 between the Bureau of Ordnance, U.S. Navy, and Johns Hopkins University. It is available in complete form from the authors, on request.
5. G. v. Békésy, *J. Acoust. Soc. Amer.* 27, 830 (1955).
6. ———, *Science* 123, 779 (1956).
7. R. G. Roush and E. T. Urbanski, *Electronics* 26, 1954 (1953).
8. Goodmans Vibration Generator, model V47, Goodmans Industries, Ltd., Wembly, Middlesex, England.
9. P. Périlhou, *J. Psychol. norm. pathol.* 40, 293 (1947).

1 April 1957

Cold-Resistant Oat Varieties also Resistant to Heat

Apparently Trabut (1) was first to indicate that red oats resist heat. His reference was to Algerian oats, which are similar morphologically to the Red Rustproof oat in this country. Several writers have agreed with early statements (2) that red oats, *Avena byzantina* C. Koch., are more heat resistant than common or "white" oats, *A. sativa*. It appears, however, that no data on heat resistance in oat plants have ever been published, except for a brief preliminary note by me (*3*). The experiments were continued and the additional data obtained confirm the preliminary results and provide additional information. The more recent data were obtained while a specially constructed heat chamber was being used.

The relative winter hardiness of the varieties listed in Table 1 has been determined (*4*), and the varietal type and morphological classification as indicated by Stanton (*5*) is shown. Bond and Victoria are resistant to many races of both crown rust and smut, Appler to many smut races as well as to some minor diseases; Bond and Fulghum are rather quick growing, large culmed oats; Winter Turf, Appler, and Victoria are late-developing, large-culmed varieties, whereas others listed in Table 1 are early, comparatively small-culmed oats.

Plants of different species, varieties, and ages were exposed to temperatures of 48.5° to 51°C for 45 minutes. Such exposures had previously proved effective in differentiating differences in heat resistance. Results from experiments indicated that some varieties of both *A. byzantina* and *A. sativa* are heat resistant, but others are not. There appeared to be little or no relationship between heat resistance and resistance to any major disease of oats. Quick-growing oats with thick culms were less heat resistant than slower growing oats with more slender culms. Many of the latter group were winter oats, whereas many but not all of the former were spring varieties. On the average, early maturing oats, whether spring or winter, appeared to be more heat resistant than late to very late varieties. There was, however, definite correlation between heat resistance and winter resistance in oats (Table 1). These data were compiled from extensive field seedings to determine winter hardiness and from heat experiments conducted on greenhouse-grown oats.

Black Mesdag, a heat-susceptible spring oat, was crossed with Lee, a heat-resistant winter variety. The F_3 behavior indicated that heat susceptibility was dominant. The segregation ratio of approximately 37 (susceptible)/27 (resistant) indicated that three factors were involved, but transgressive segregation for increased heat resistance above that of the Lee parent also was observed. Transgressive segregation resulting in increased winter resistance in winter × spring oat crosses likewise has been observed. Since heat and winter resistance appear to be correlated, transgressive segregation for increased heat resistance might be expected in certain crosses.

Oat plants apparently are more resistant to heat in the early boot stage than earlier or later in their development. Maximum resistance to heat was reached in plants some 40 to 45 days old in spring varieties and in plants 45 to 50 days in the slower-developing winter oats. Heat resistance in both groups dropped precipitously thereafter.

Heat resistance in oats was greater in plants after exposure on bright days than it was in those treated on dark days. In winter oats, an apparent conditioning response resulted from exposure to warm temperatures prior to heat treatment. This was not apparent in spring oats.

Table 1. Relative winter hardiness and heat resistance of 12 varieties of oats (Fulghum check, 100 percent).

C.I. No.	Type and variety	*Avena* species	Winter survival (%)	Heat survival (%)
		True winter		
3168	Fulwin	*A. byzantina*	137.6	123.4
3218	Bicknell	*A. sativa*	130.1	124.7
2505	Hairy Culberson	*A. sativa*	129.8	122.2
2499	Pentagon	*A. byzantina*	128.2	103.1*
947	Tech (V.P.I. No. 1)	*A. sativa*	125.1	105.5*
3296	Winter Turf	*A. sativa*	120.1	111.2
2042	Lee	*A. sativa*	116.8	100.0*
3217	Culred	*A. byzantina*	108.5	120.0
		Intermediate winter		
1815	Appler	*A. byzantina*	100.3	99.8
708	Fulghum (check)†	*A. byzantina*	100.0	100.0
		Spring		
2733	Bond	*A. byzantina*	63.8	68.2
2401	Victoria	*A. byzantina*	46.8	43.0

* Additional data, not fully comparable with those shown, reveal that this variety is somewhat more heat resistant than indicated here.
† The average heat survival for Fulghum was 56.3 percent of 451 plants tested, and it survived 56.1 percent in 560 field-grown nurseries in which differential winter killing was recorded.

It appears probable that those physiological factors conditioning cold resistance in the oat plant cell also condition heat resistance. This suggests the possibility of testing for winter resistance in oats by the cheaper, more easily conducted heat test. Exploratory tests have indicated that heat resistance and winter resistance may also be associated in wheat and in barley.

FRANKLIN A. COFFMAN
Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland

References and Notes

1. L. Trabut, *J. Heredity* 5, No. 2, 74 (1914).
2. S. C. Salmon and J. H. Parker, "Kanota: an early oat for Kansas," *Kansas Agr. Expt. Sta. Circ. No. 91* (1921); E. Archer, "A classification and detailed description of the oats of Australia," *Inst. Sci. and Ind. Melbourne Bull. 23* (1922); W. W. Mackie, "Oat varieties in California," *Univ. Calif. Agr. Expt. Sta. Bull. 467* (1929).
3. F. A. Coffman, *J. Am. Soc. Agron.* 31, 811 (1939).
4. ———, *U.S. Dept. Agr. Circ. 623* (1941); *J. Am. Soc. Agron.* 34, 651 (1941); *J. Am. Soc. Agron.* 39, 1027 (1947); *Agron. J.* 47, 54 (1955).
5. T. R. Stanton, *U.S. Dept. Agr. Tech. Bull. 1100* (1955).

26 February 1957

Singing Female Canaries

Pet-bird dealers have reported that some of their imported canaries sing as typical males for a time but later refuse to sing. Some have been identified as females. One dealer stated that he would no longer handle imported birds because of complaints from customers.

Since it is known that female chickens and turkeys that are treated with male sex hormone will give voice in a manner similar to males (*1*), treatment of the imported canaries with hormones was suspected. To determine whether female canaries would "sing" after receiving male sex hormone, birds were treated with this hormone.

Nine female canaries, young but fully grown, were selected for the test. Five were injected with 0.1 ml each of microcrystalline suspension of male sex hormone, testosterone phenylacetate (Perandren, Ciba). Each bird was given a single injection per test period. Each injection of 0.1 ml of the preparation contained 5 mg of active material. Four birds were not treated.

Nine days after the injection, two of the treated canaries made a series of chirps that were more closely connected than previous chirps had been. Twelve days after the injection, all treated birds were definitely "singing," although the song lasted for only a few seconds at a time. In the following days the length of sustained song became greater, and the song was indistinguishable from that