ON TRANSITION IN THE LIGHT OF X-RAY FILMS

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In my discourse at the IV[th] International Congress of Phonetic Sciences in Helsinki in 1961, I already touched to some extent the subject of transitions; namely transitions of the components of some Finnish diphthongs. For demonstrational purposes I used a special piece of equipment called ADAM (Apparatus for Demonstrating Articulatory Movements), which had just been developed at our Phonetic Institute. In the meantime some parts of this apparatus, especially the contourtape, plastic die plates, and the illumination showing through the pierced back plate have been improved to simplify the process of the diagramming of X-ray films and the photographing of the separate pictures thereof. Fig. 1.

Today I shall as examples handle some *VC*-, *VV*-, *CC*- and *CV*- transitions as they appear in some Finnish words and are shown in the successive single frames of X-ray films and in the corresponding segments of spectrograms.

When analysed transitions from that X-ray sound film for whose speed was chosen 48 frames/sec. I used the following method. Segments of speech corresponding to film frames were diagrammed with the help of the apparatus (ADAM) mentioned above. Various types of spectrograms were made of the series of words where the

Table 1. The transition of *pä* (in the word *täytyypä*)

		ä 1		*ä*2		*ä*3	
F	Print	*c/s*	*db*	*c/s*	*db*	*c/s*	*db*
*F*0	*NB*	321		318		311	
*F*1	*VP*	675	30	950	36	975	42
*F*1	*WB*	800		975		925	
*F*1	*NB*	642		954		933	
*F*2	*VP*	1950	36	1950	36	1900	36
*F*2	*WB*	1875		2025		2000	
*F*2	*NB*	1826		1908 + 2226		1866 + 2177	
*F*3	*VP*	2950	24	3200	24	3275	24
*F*3	*WB*	2925		3200		3275	
*F*3	*NB*	2889		3180		3110 + 3421	

transitions being examined occurred. For this purpose were used either the Kay Sonagraph (Model 661-A) or the Voiceprint Laboratories Sound Spectrograph (Model 4691 A) recently obtained by our Institute in Helsinki. For analization of the transitions the formant data were computed from the end section of the segments representing the frames. The actual speed of this film was 47,4 frames/sec.

In Fig. 2 is seen the normal spectrogram made with the Voiceprint Spectrograph using a wide band filter and flat shaping of amplitude. By vertical lines the divisions

Table 2. The transition of *tä* (in the word *täytyypä*)

		*ä*1		*ä*2		*ä*3		*ä*4	
F	Print	*c/s*	*d/b*	*c/s*	*d/b*	*c/s*	*db*	*c/s*	*db*
*F*0	*NB*	290		293		304		304	
*F*1	*VP*	285	12	900	30	950	36	925	30
	WB	700		900		925		925	
	NB	870		876		912		912	
*F*2	*VP*	2600	6	2375	24	2175	30	2100	24
	WB	2650		2375		2250		2125	
	NB	2610		2344		2128+2432		2128	
*F*3	*VP*	3700	18	3700	18	3675	18	3675	24
	WB	3675		3625		3650		3650	
	NB	3480 + 3770		3516		3648		3648	

NB = Narrow band, linear, high shaping
WB = Wide band, linear, high
VP = contour, high voiceprint spectrogram.

Table 3. The transition of *äy* (in the word *täytyypä*)

		*ä*8		*ä*9		*ä*10		*ä*11	
F	Print	*c/s*	*d/b*	*c/s*	*db*	*c/s*	*db*	*c/s*	*db*
*F*0	*NB*	370		385		397		416	
*F*1	*VP*	1100	42	950	30	825	36	825	42
	WB	1100		950		800		750	
	NB	1110		770+1155		794		832	
*F*2	*VP*	2400	36	2350	36	2350	42	2475	36
	WB	2450		2350		2175		2475	
	NB	2220+2590		2310		1985+2382		2496	
*F*3	*VP*	3575	30	3475	36	3550	36	3475	36
	WB	3675		3500		3350		3300	
	NB	3700		3465		3176+3573		3328	

of separate segments corresponding to film frames have been made clearer. The test word is the Finnish word *täytyypä* [*tæyty:pæ*] 'one ought to.'

Tables 1—3 show also the results of the formant data obtained by using three spectrogram modes.

The explosions of plosives in the transitions [*pæ*] and [*tæ*] are included to the first segment of the vocoid [æ]. The duration of each segment corresponding to the frame frequency was 21,1 msec.

In the transition [*pä*] formants 1, 2 and 3 rise due to the low labial loci in changing over from segment *ä*1 to segment *ä*2. Their frequencies are already invariable when reaching the next segment, *ä*3, but the amplitude of F1 rises from 36 to 42 db. In Fig. 3—6 the smallest distance between the labial contours grows gradually frame by frame as indicated by the following measurements: *ä*1 7 mm, *ä*2 10 mm, *ä*3 16 mm. Measuring is easy using the pointed pattern in the back plate of the apparatus; the distances of the points, which are equal in size, correspond to 4 mm of life-size of the subject's articulatory organ. The scale of the apparatus is 5-fold. Measured from the contour spectrogram this labial transition took about 40 msec. (Fig. 7).

In the transition *tä F*2 is continuously falling during the course of four successive segments as shown by the frequencies 2650—2375—2250—2125 (WB). The locus of F2 in this transition [*tä*] is rather high (about 2600) mostly due to the fact that the test person was very young (a 12-years old boy), but also depending on the post-dental-prealveolar position of the Finnish [*t*]. Examining the movements of the tip of the tongue in the corresponding frames, we find that the profile of the tongue is not completely convex and non-apical until the fifth segment, that is, around 85 msec. (4×21,1 msec. = 84,4 msec.). See Figs. 8—13. The apical distance (between the tip of the tongue and the alveolar arch) is increasing in millimeters, frame by frame, in the following way: *ä*1 and *ä*2 5 mm., *ä*3 6 mm., *ä*4 7 mm., and *ä*5 14 mm.

		*ä*12		*y*1		*y*2	
F	Print	*c/s*	*db*	*c/s*	*db*	*c/s*	*db*
*F*O	*NB*	418		420		414	
*F*1	*VP*	720	24	425	24	425	24
	WB	575		425		425	
	NB	418 + 836		420		414	
*F*2	*VP*	2500	36	2525	36	2475	36
	WB	2525		2500		2450	
	NB	2508		2520		2484	
*F*3	*VP*	3325	36	3350	24	3325	24
	WB	3325		3350		3275	
	NB	3344		3360		3312	

In the transition of the components of the diphtong [*äy*] three clear stages can be distinguished. 1) F1 noticeably starts to fall (1100—950 c/s) at phase *ä*8—*ä*9. 2) F2 rises to the level of the next component [*y*] (2500 c/s) at phase *ä*10 — *ä*11. 3) F1 falls finally to the level demanded by [*y*] (400 c/s) at phase *ä*12 — *y*1 (Fig. 14). In the corresponding frames we can see that the contraction of the narrowest point of the tongue channel begins at phase *ä*8 and ends only about phase *y*1 (from 21 to 13 mm). At the same time we can see the narrowest point of the pharyngeal channel extending from 11—18 mm. The length of the whole transition is thus about 5 segments, or 100 msec. The labial channel in the frames *ä*12, *y*1 and *y*2 has the following measurements: 24 mm in the last [*ä*] frame, 20 mm in the first and 8 mm in the second [*y*] frame (Figs. 15—21).

Without explaining the corresponding acoustic phenomena, I shall show some diagrams made from a film where the rate of 80 frames per sec. was used (Fig. 23). We shall compare the last frames of the preceding sounds with the first ones of the later. In Fig. 24 the tip of the tongue has not yet quite reached the alveolar arch as the vowel [*e*] is just changing into the Finnish medioalveolar [*s*] sound in the test word *Esko* (a Finnish male name). The narrow opening of the front teeth and the position of the mediodorsum of the tongue are already the same as in the next frame 12,5 msec. later (Fig. 25). The transition of [*es*] during two successive frames, that is 25 msec., is demonstrated in Fig. 26 where the two phases of movement are photographed simultaneously on one and the same diagram. The CC-transition [*sk*] of the same test word is shown in Fig. 27 as above in two successive phases of transition. One can see the tongue preparing itself to the mediopalatal occlusion of [*k*] in the frame of the last phase of [*s*]; the slight upward movement (5 mm) of the back of the tongue and at the same time the quick release movement (4 mm) of the tip very skilfully produce the transition from [*s*] to [*k*]. The jaw has hardly had time to change its position at all during this dual picture.

The following diagram (*u*)*r* + (*u*)*r*2 (Fig. 28) concerns this same [*r*] contoid, in which the position (*u*)*r*2 corresponds to the wider phase in the tremulation of the front part of the tongue. The narrower phase of the tremulation has been diagrammed from the preceding frame. The duration of one vibration of the tongue is about 25 msec. and the tremulation has a frequency of about 40/sec. in this contoid. The narrower phase resembles an apical medioalveolar occlusion as in the Finnish plosive [*d*], but in this phase the air flow is going through a very narrow groove.

In the near future we will investigate the preceptional level of those transitions of frame diagrams and spectrograms. For this purpose we will use our transistorized photocell segmentator listening to the desired cut sequences of the optical sound of the X-ray motion pictures.

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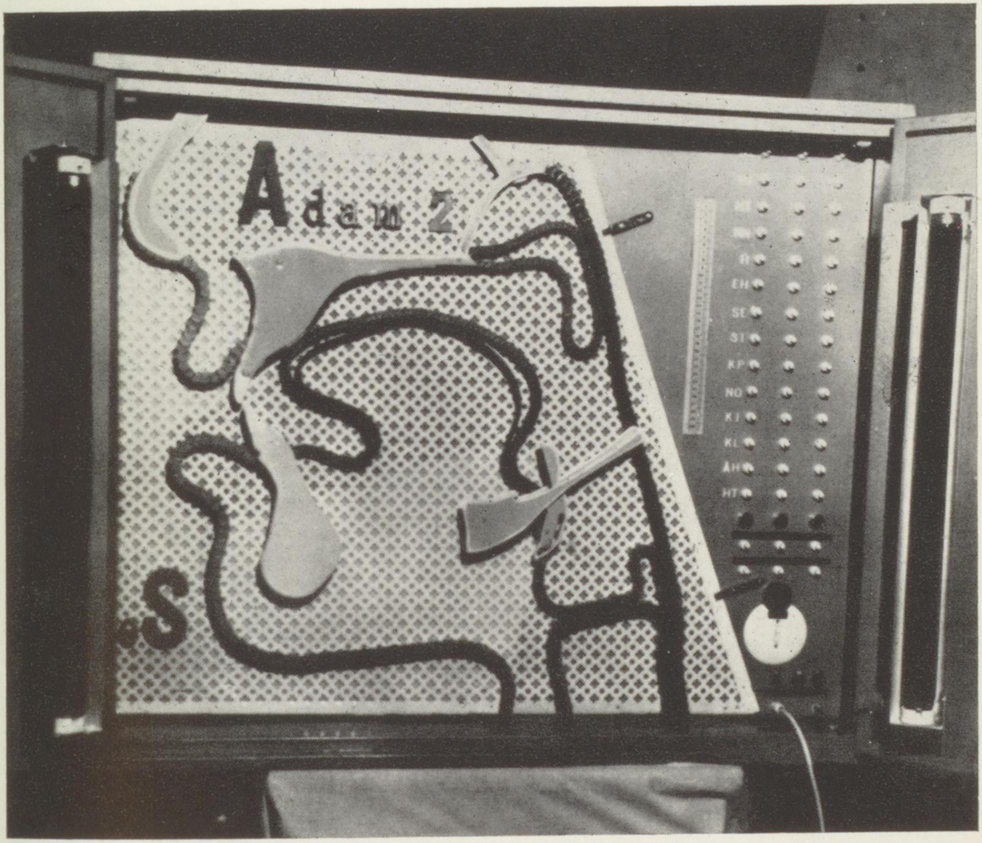
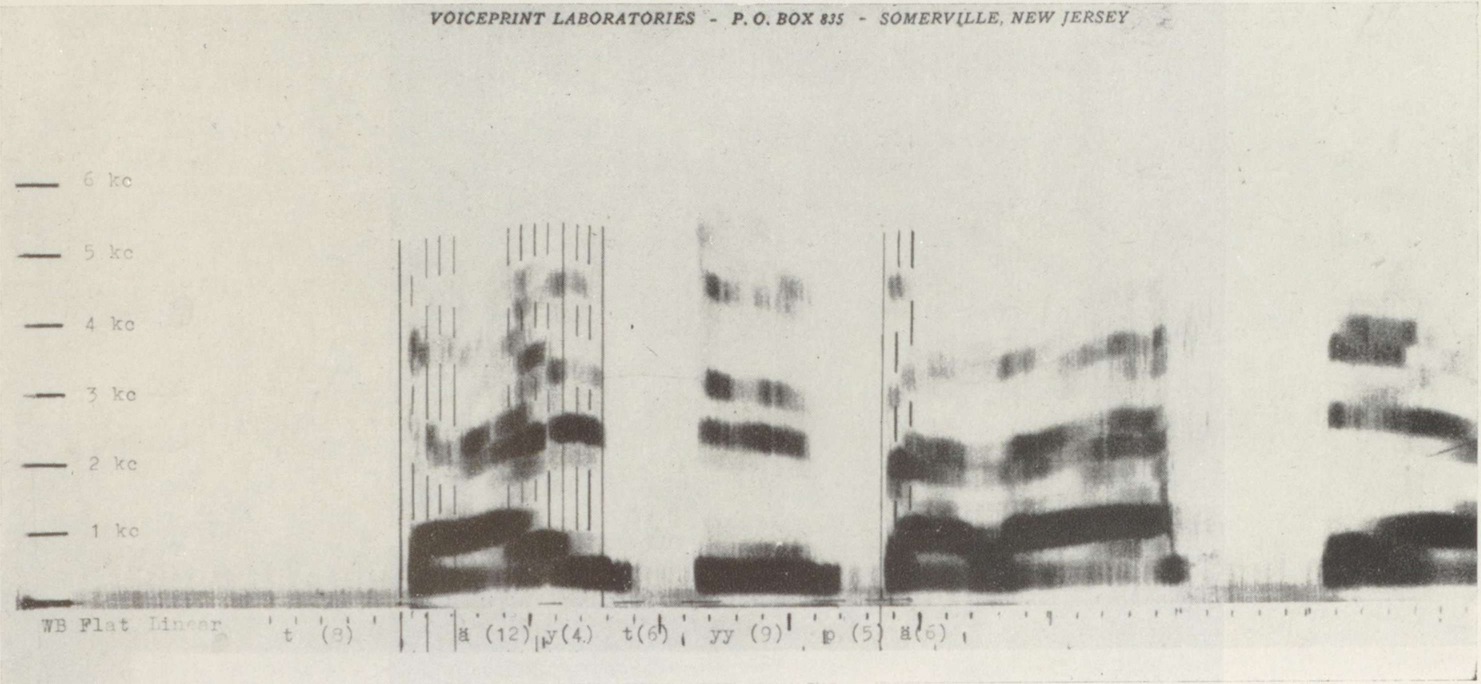


Fig. 1.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6 kc
5 kc
4 kc
3 kc
2 kc
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WB Flat Linear
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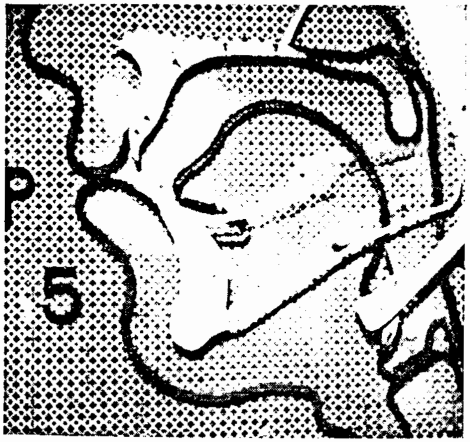
ä (12)
y(4)
t(6)
yy (9)
p (5)
ä(6)

Fig. 2.



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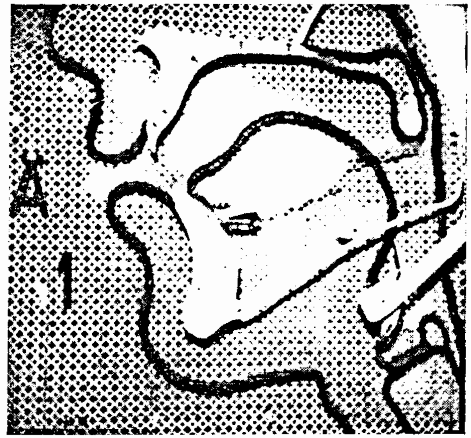

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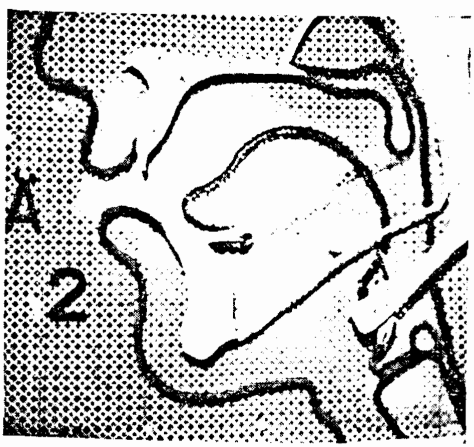

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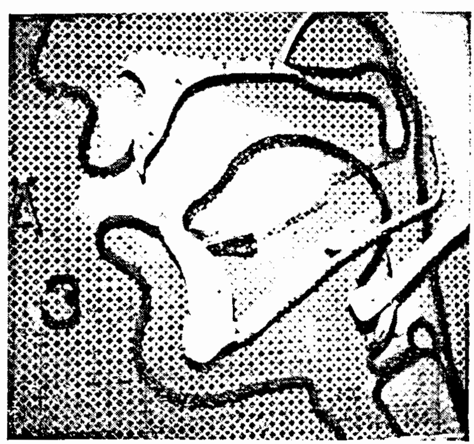

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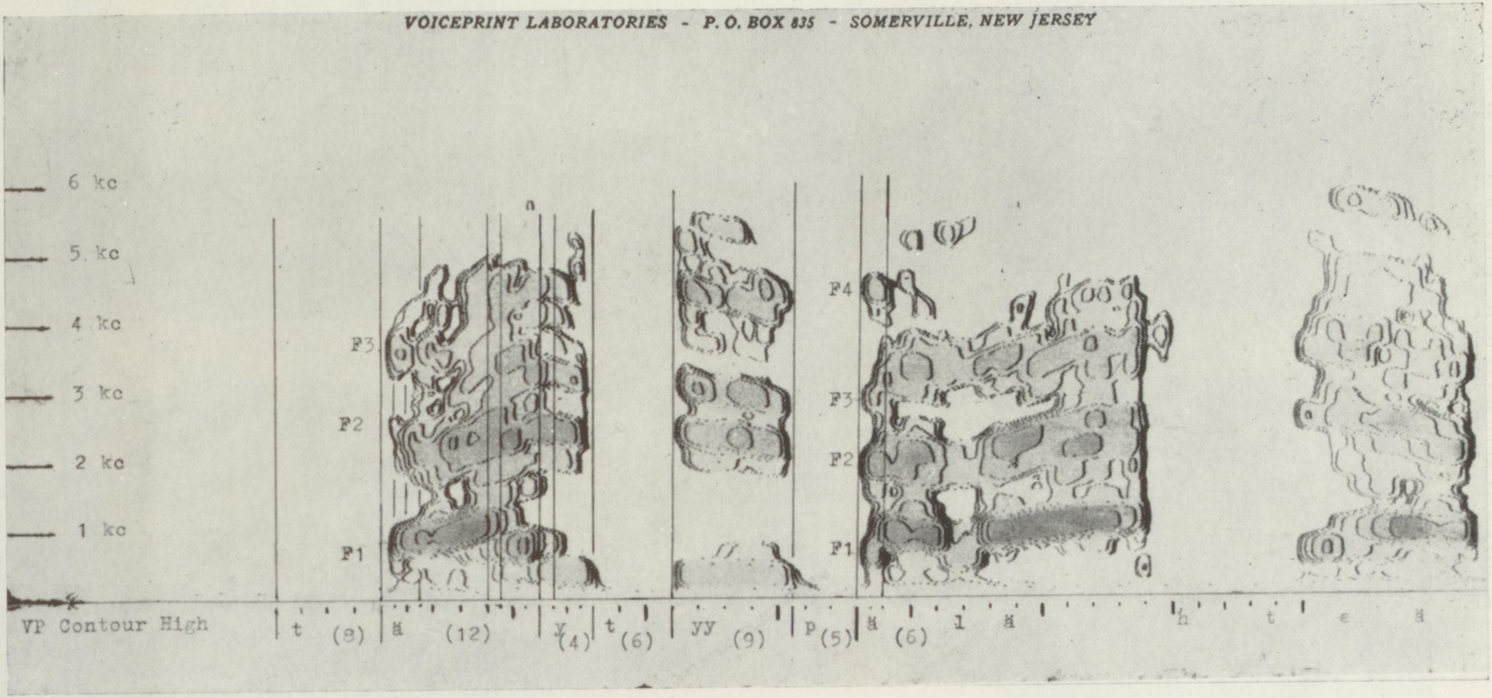
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6 kc
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VP Contour High
t (8) ä (12) y (4) t (6) yy (9) p (5) ä (6) l ä h t ɛ ä

Fig. 7.

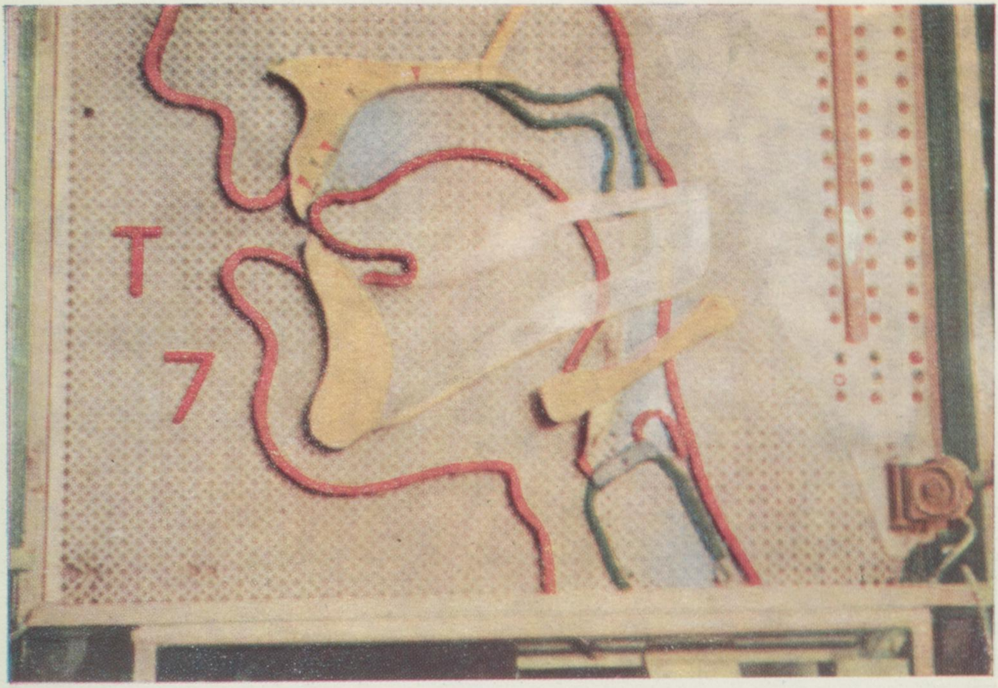


Fig. 8

Fig. 9

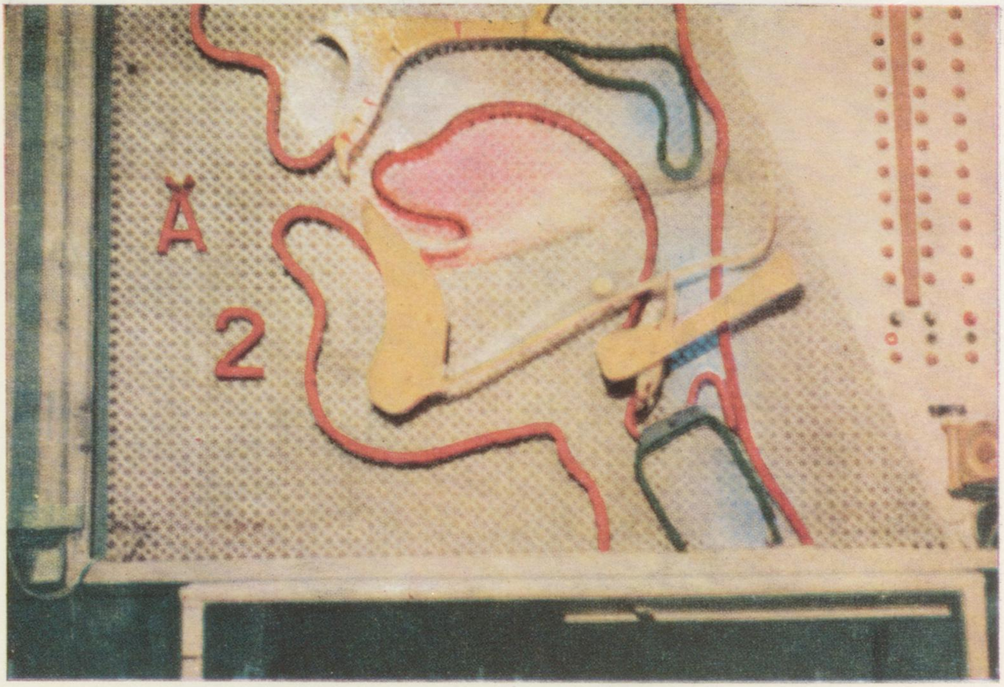
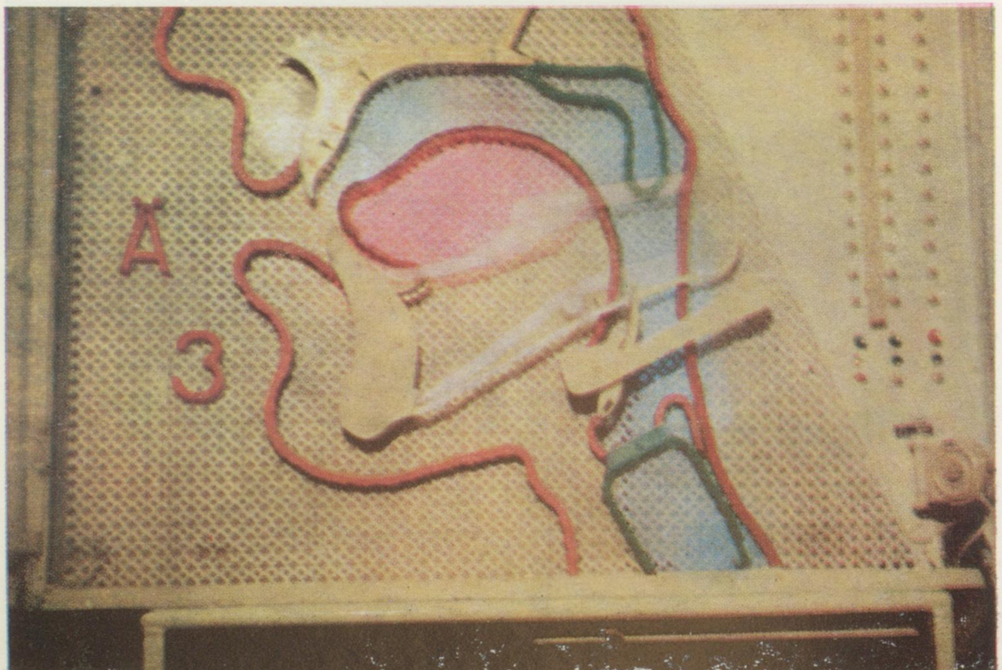


Fig. 10



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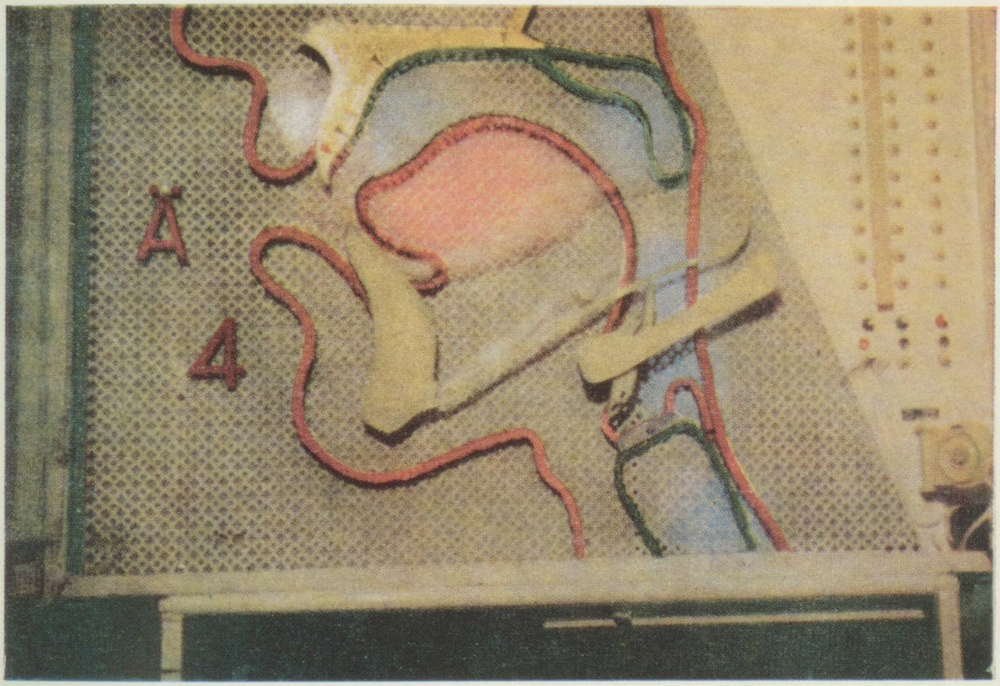

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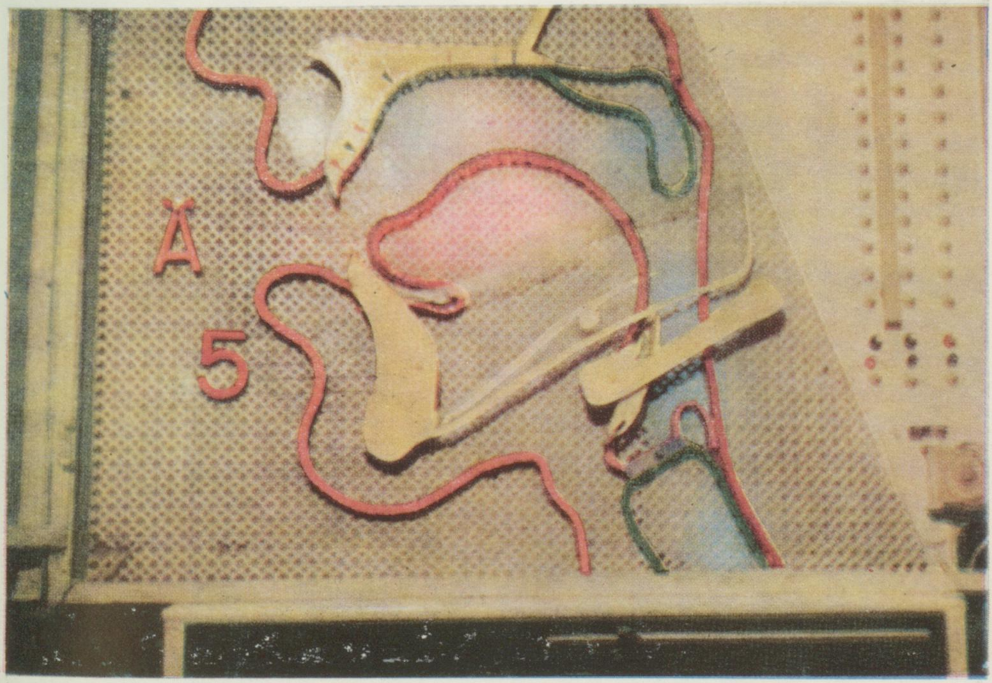

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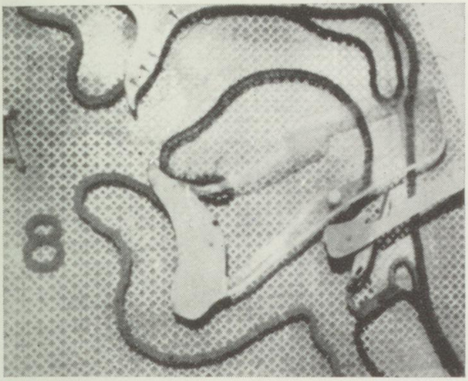

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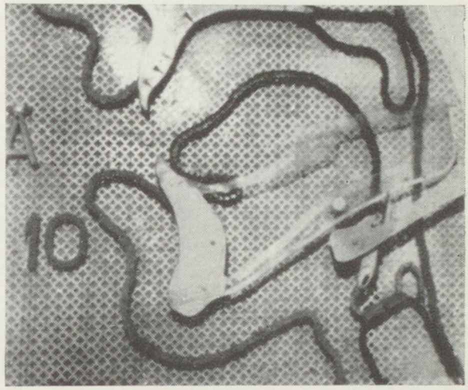

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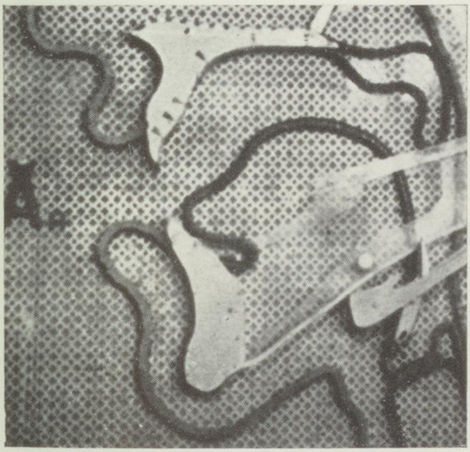

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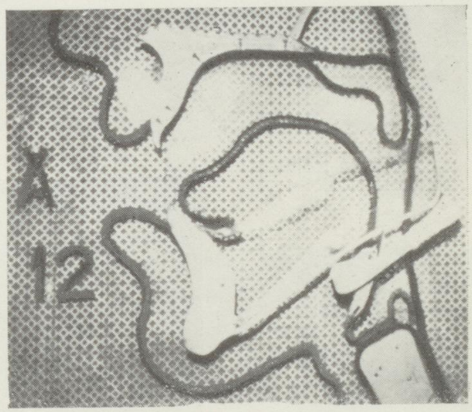

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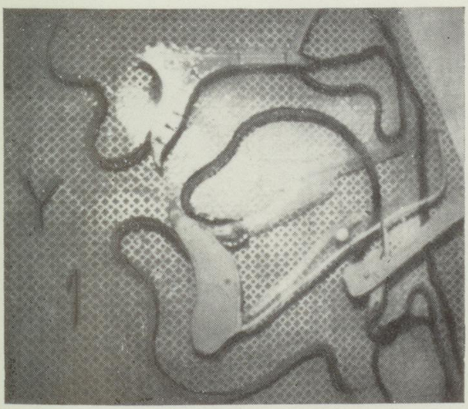

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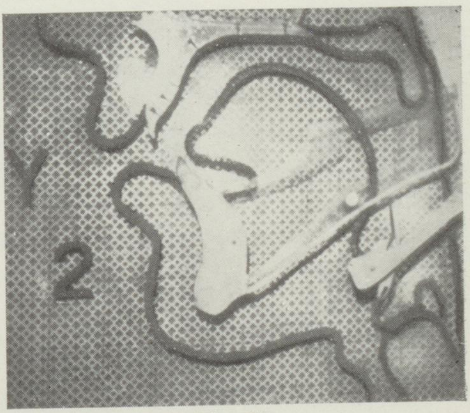

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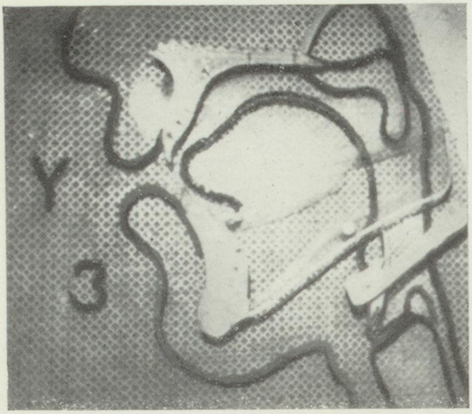

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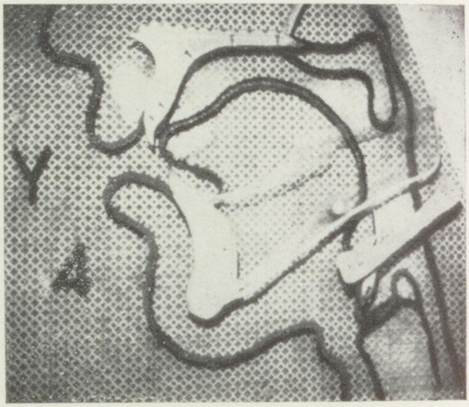

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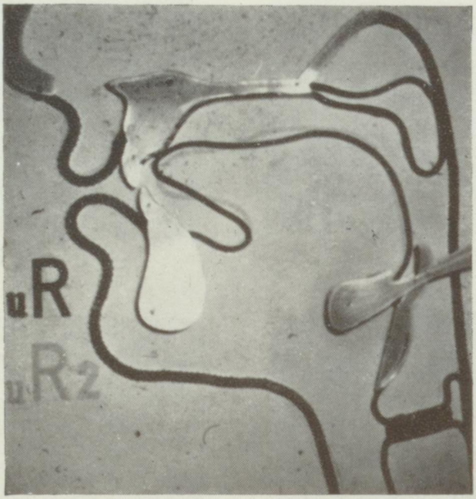

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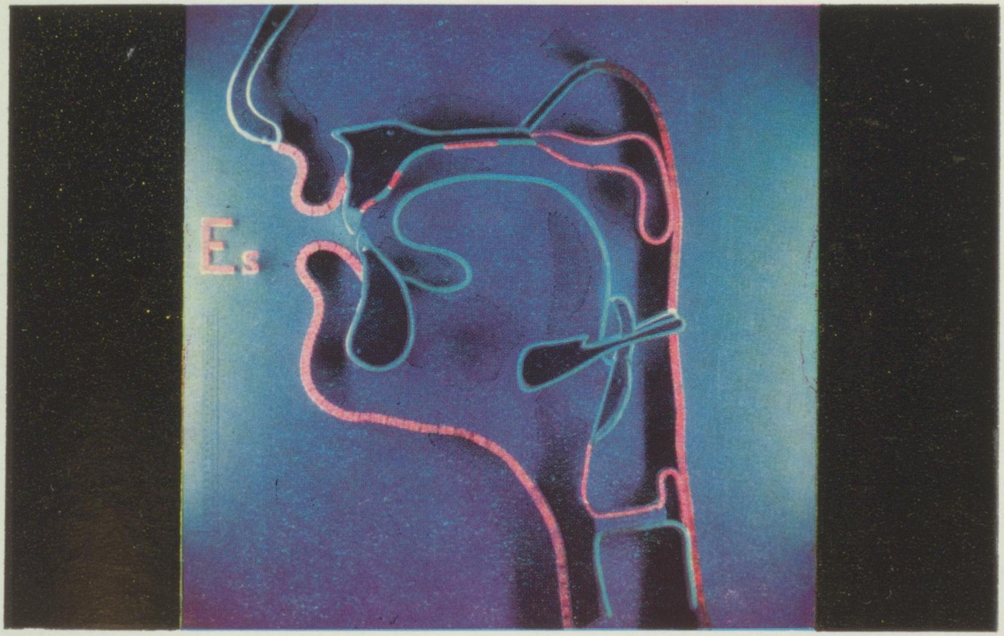

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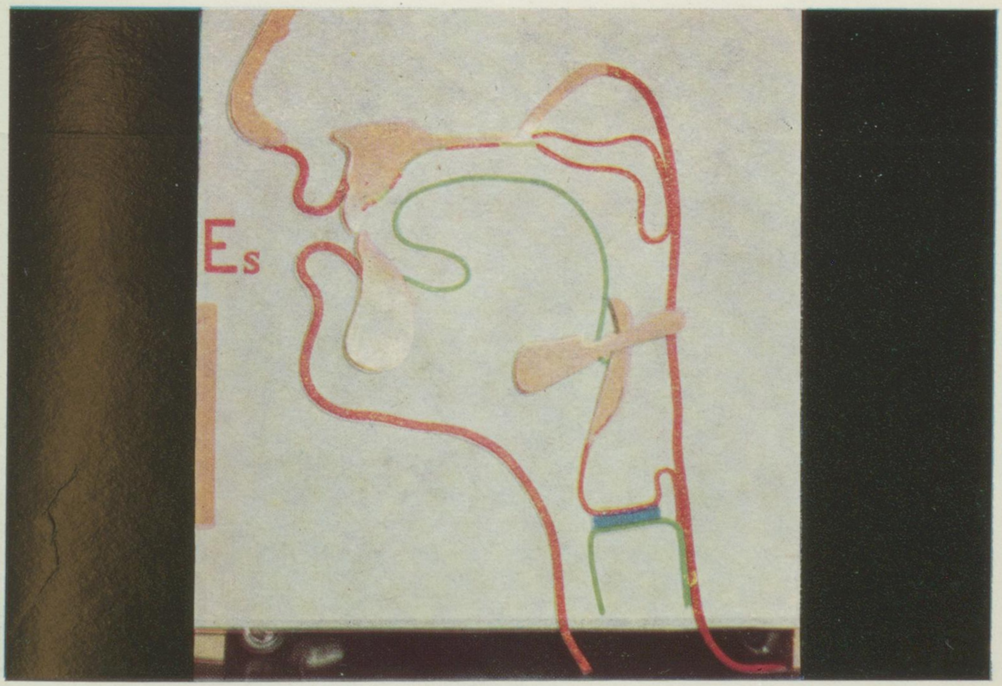

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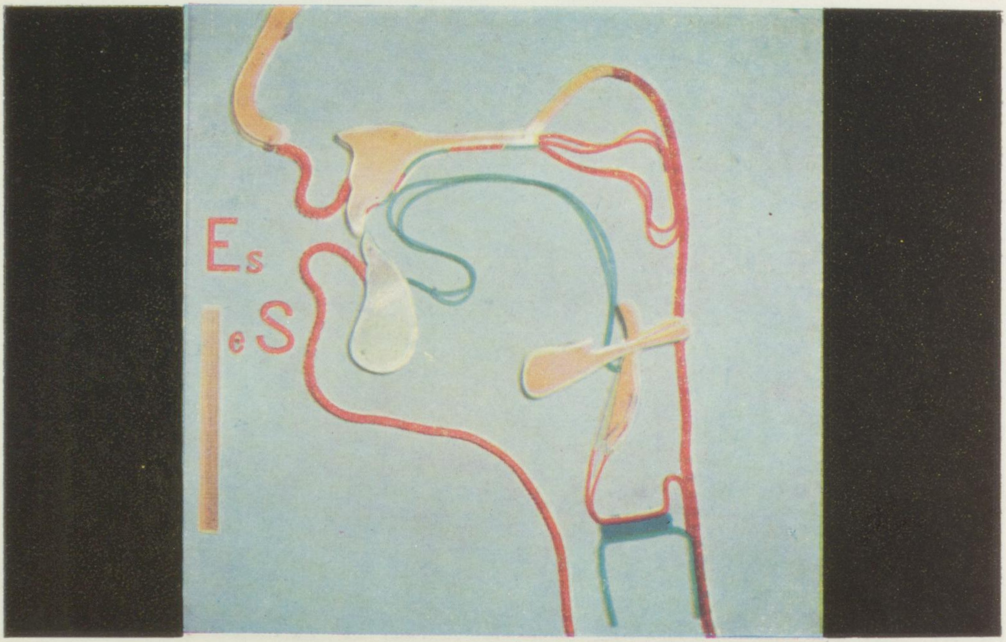

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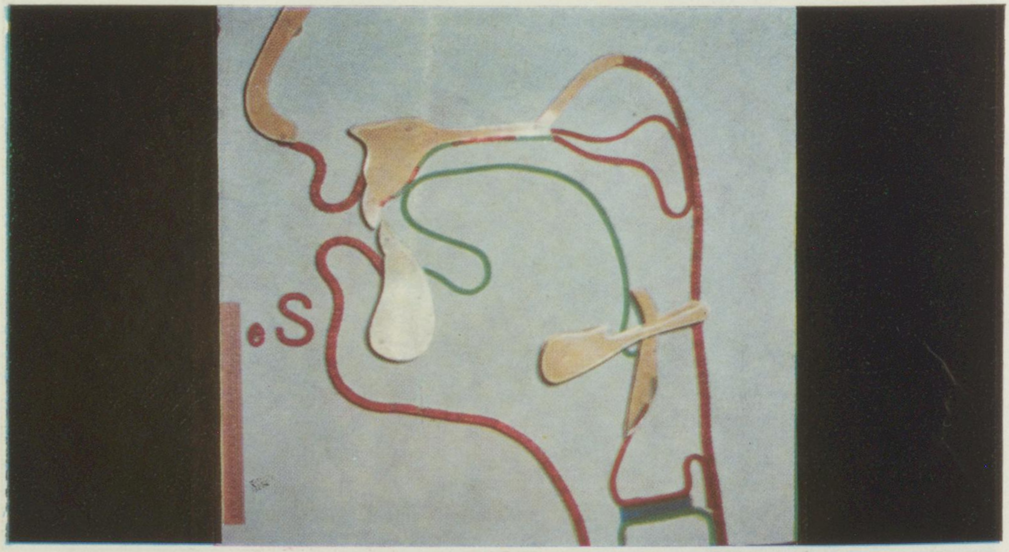

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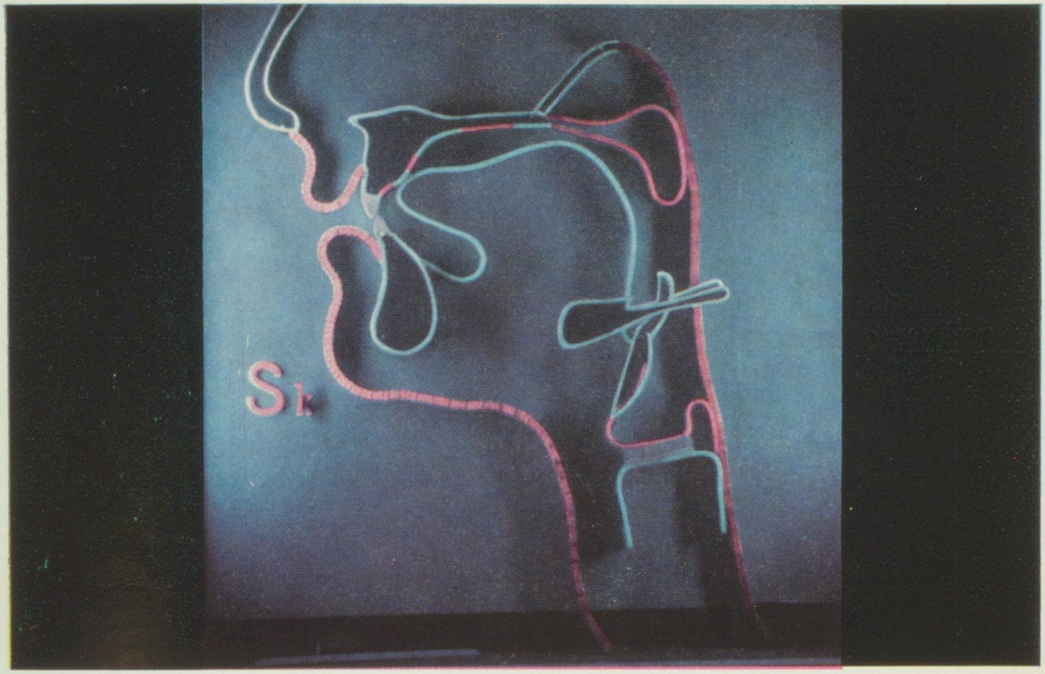

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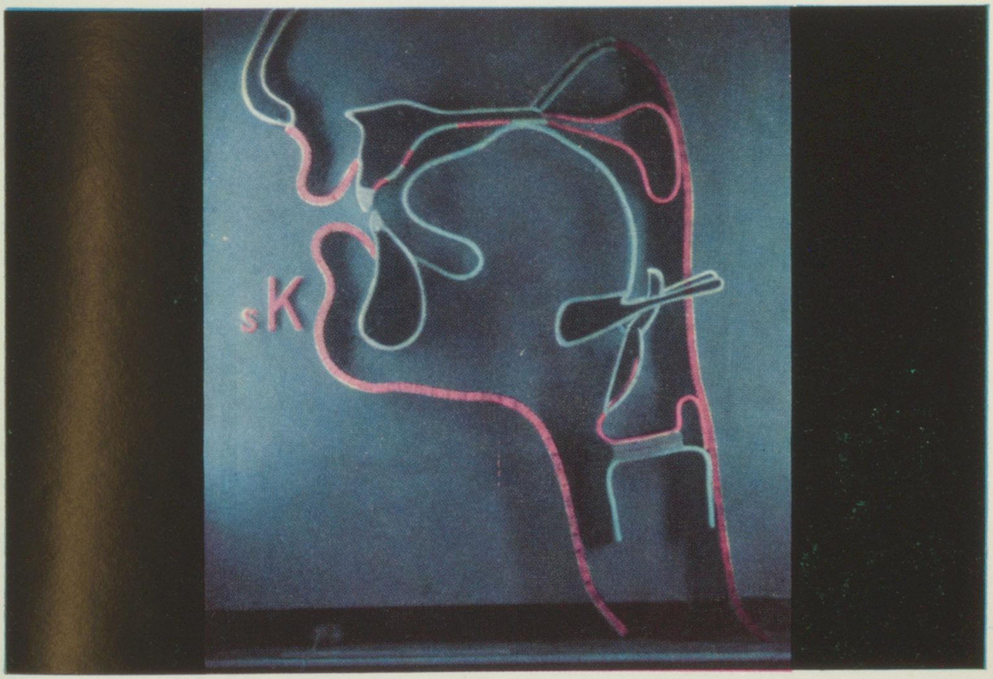

Fig. 27