

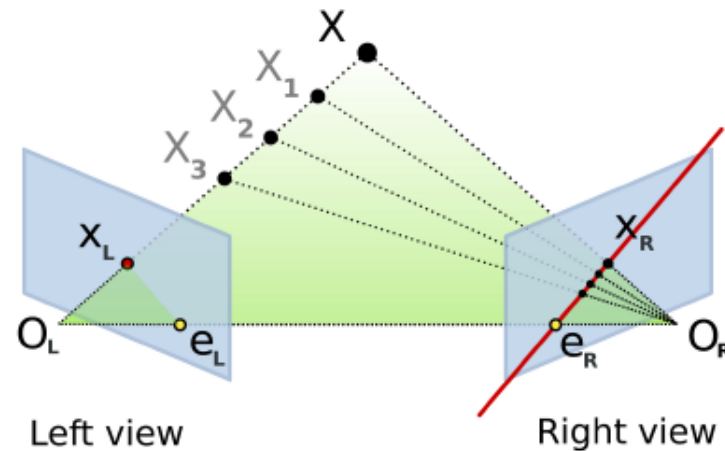
Binocular Stereo

# Goal of Binocular Stereo

- Estimate Depth.
  - Leonardo da Vinci
  - Wheatstone.
  - Aerial Photography.
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- Julesz Random Dot Stereograms.
  - Detect objects in camouflage?

# Geometry of Stereo: Depth by Triangulation

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**Fig. 9.** Stereopsis and epipolar lines. A point  $x$  in three-dimensional space gets projected onto positions  $x_L$  and  $x_R$  in the left and right eyes. This uses a pinhole camera model of each eye where the eye is specified as a plane (in grey) and  $O_L$  and  $O_R$  represent the centers of projection. Observe that all points on the plane defined by  $O_L, O_R$  and  $x$  get projected onto straight lines  $e_L$  and  $e_R$ , the corresponding *epipolar lines*, in the two eyes. To illustrate this we show the projections of a few points  $x_1, x_2, x_3$  onto the right eye. If we alter the position of the point  $x$  in space then we will get a family of corresponding epipolar lines. The *epipolar line constraint* states that points on an epipolar line in one eye can only be matched to a point in the other eye on the corresponding epipolar line. In this picture the eyes are fixating at a point. But if the eyes are parallel to each other the fixation point will be at infinity and the epipolar lines will be parallel to each other in the two eyes (or images).

# The Correspondence Problem.

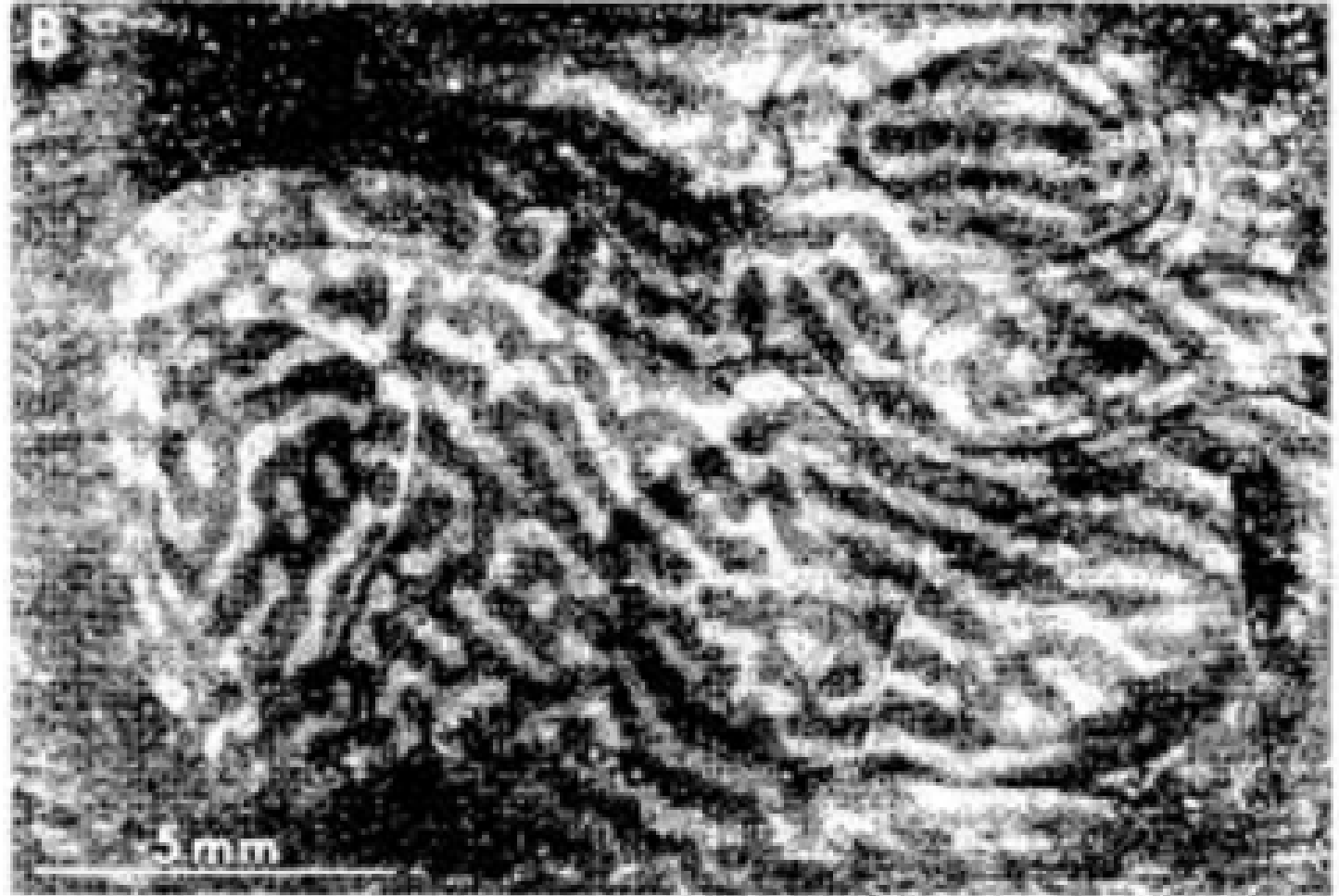
- Bela Julesz Random Dot Stereograms:



**Fig. 5.** Binocular stereo of the fox for real images and for Julesz random dots stereograms. The left two images are a stereo pair (the left and right images) of a fox so that, when fused (e.g., by a stereo viewer presenting the left and right images to the right and left eyes, respectively), they yield the three-dimensional shape of the fox. The right two images are stereo pairs of random dot images of a fox. When fused, they also give the three-dimensional shape of the fox.

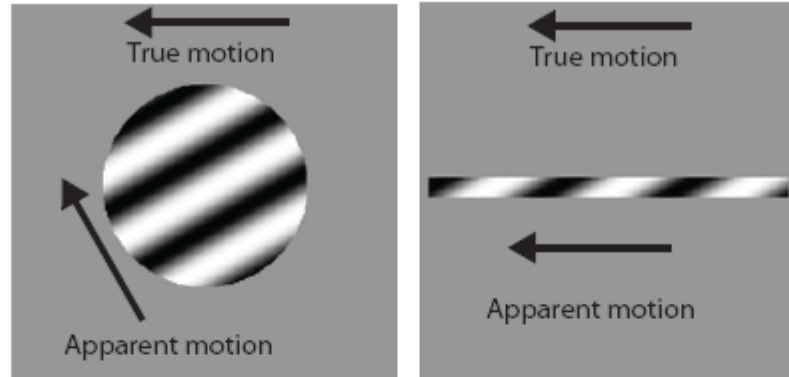
# Ocular Dominance Columns

- Stereo in V1?



# Motion Estimation

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**Fig. 7.** These images show black and white bars whose *true motion* is leftwards viewed through two apertures (circular and rectangular). But the motion is locally ambiguous because we can only directly observe the motion component normal to the bars (we cannot detect if there is any motion tangential to the bars) and so the observed stimuli is consistent with many possible motions. The human visual system uses constraints to resolve these ambiguities. For these stimuli, humans assume that the motion is as slow as possible and hence is perpendicular to the bars (i.e. assuming that the unobservable tangential component is zero), as indicated by the *apparent motion*. More generally, as discussed in section (4.4) humans tend to assume that motion is slow and smooth. See demo 4e.