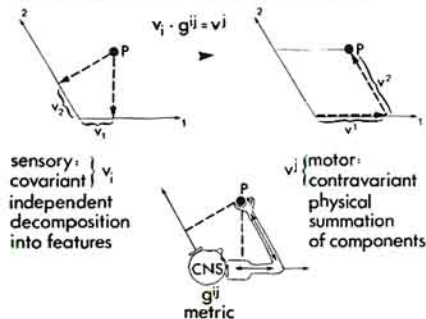
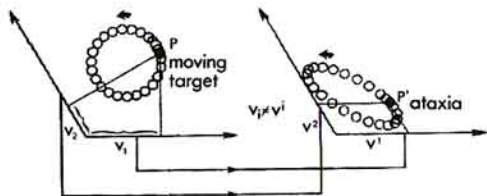


### A SYMBOLIC (SIMPLEST GENERAL NON-ORTHOGONAL) SENSORIMOTOR COORDINATE SYSTEM



### B DYSMETRIA: COVARIANT COMPONENTS USED DIRECTLY AS CONTRAVARIANT EXECUTORS



### C TRANSFORMATION OF SIMULTANEOUS COVARIANTS BY A SPACE METRIC

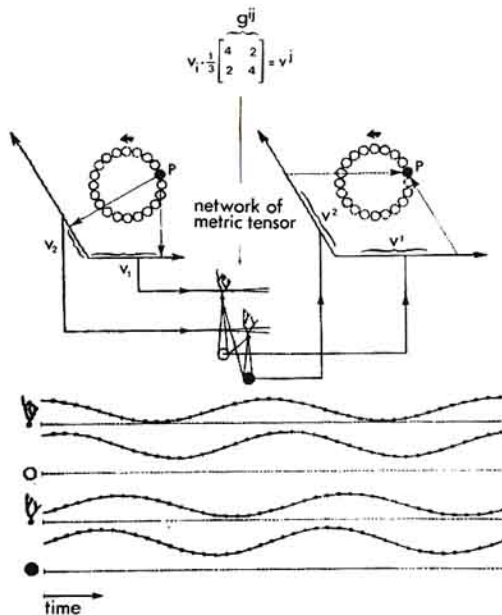


Fig. 3. A demonstration, in a symbolic sensorimotor system, of the differences and the relation of sensory and motor coordinates. A: As the simplest general model of sensorimotor systems, an identical pair of two-dimensional sensory and motor reference frames are presented with general (oblique) coordinate axes at a 120° angle. The sensory coordinate system is composed of two sensors yielding independently-established covariant components  $v_i$ , the vector being assigned to the reference-frame invariant physical entity of a location  $P$ . The motor coordinates  $v^j$  are expressed contravariantly in the same frame of reference (since they physically must add up to the invariant). The  $g^{ij}$  contravariant metric tensor expresses the transformation from the sensory covariant components into motor contravariants. Sensory- and motor-frames of reference are rarely identical in biological systems. The model of acoustic sensory and limb motor frame (in A) is to stress that the same version of the vectorial expressions cannot be used in both sensory and motor systems even if the frames of reference were identical (cf. B). B: Dysmetric transfer: covariant sensory components used directly for motor execution. Without a metric transformation the covariants yield a distorted motor performance. C: Covariant-contravariant transformation through a matrix expressing the metric tensor, resulting in a proper motor execution. The network, implementing the metric tensor  $g^{ij}$  is shown by a symbolic neuronal circuitry, comprised of two parallel fibers connecting to each of the two Purkinje cells, which, in turn, send their axons to both cerebellar nuclear cells shown by open and full circles (for other possible network implementations of the same matrix see Fig. 2A). Neither the sensory, nor the motor signals in this Figure are permitted to incorporate any time delay: all signals here are synchronous, referring to simultaneous events. The activities of the neurons in the network are shown as a function of time in the bottom part of C.