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Intrinsic free energy in active nematics

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Dense active systems spontaneously generate turbulent-like flow states where the velocity field is highly disordered, with a continually changing pattern of vortices. Examples include mixtures of microtubules and molecular motors (the machinery that acts as a cellular engine or cells themselves), bacteria, vibrating granular rods, flocks of birds and schools of fish. We model such active systems using continuum theory of an active nematic to show that active turbulence develops in two stages: (i) ordered regions undergo an intrinsic hydrodynamic instability generating lines of strong deformations, (ii) the lines relax by forming oppositely charged pairs of topological defects. We demonstrate both analytically and numerically, that the activity can induce an effective free energy that enhances ordering in extensile systems of active rods and in contractile suspensions of active discs. We argue that this occurs because any ordering fluctuation is enhanced by the flow field it produces. A phase-diagram in the temperature-activity plane compares ordering due to a thermodynamic free energy to that resulting from the activity.