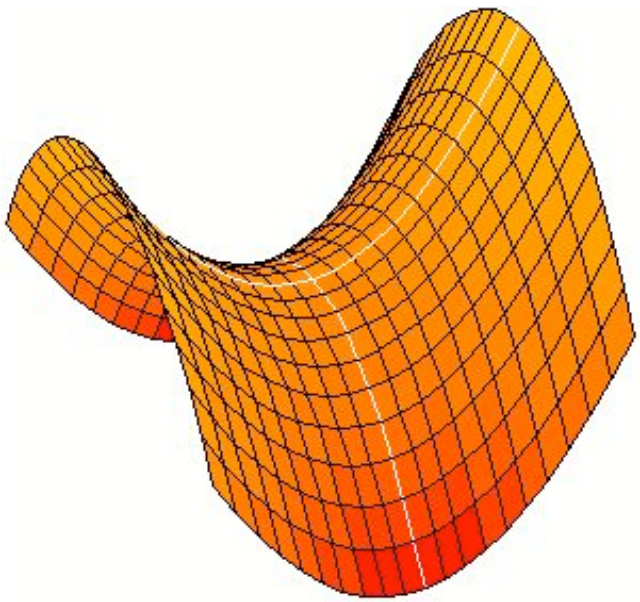
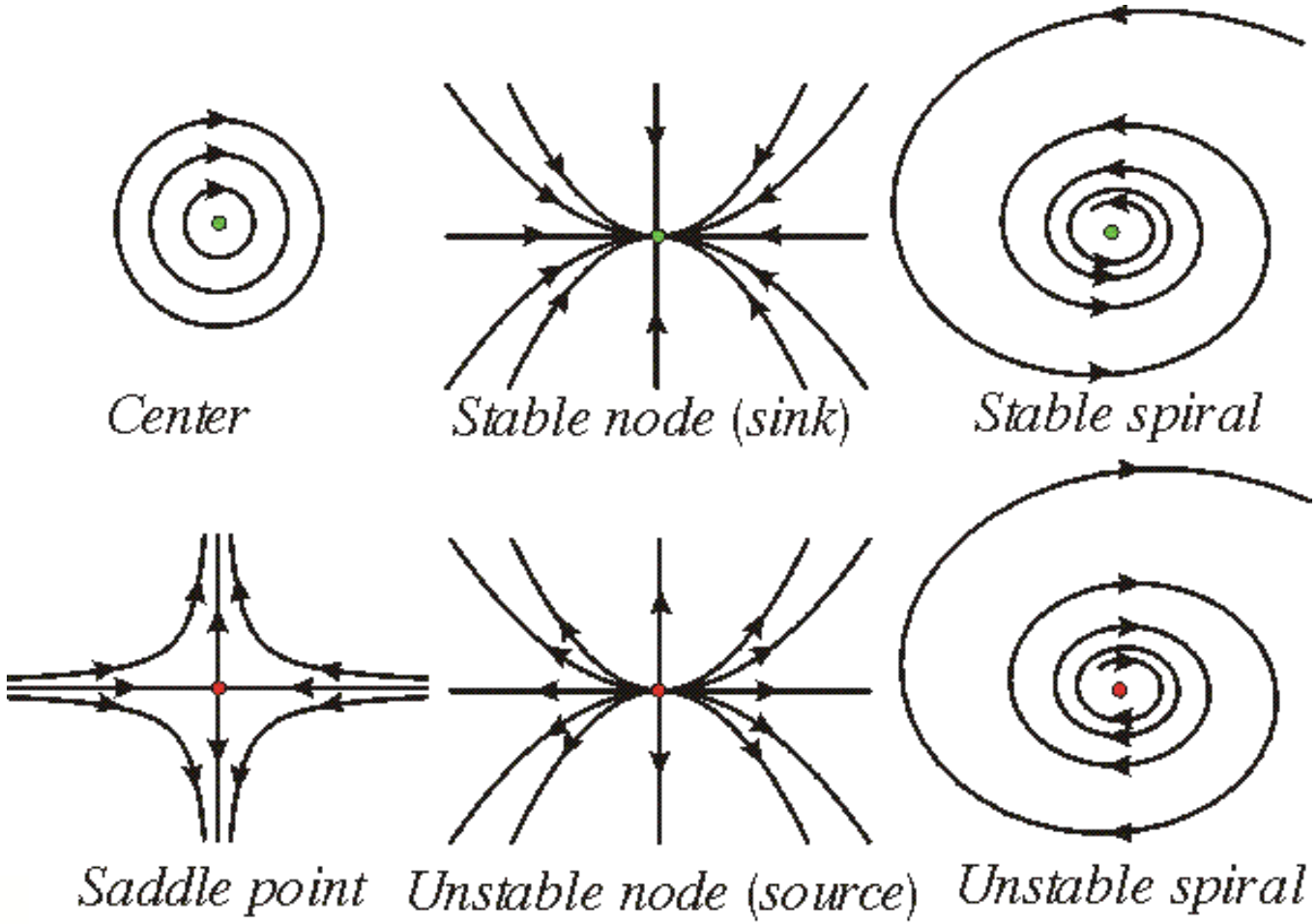
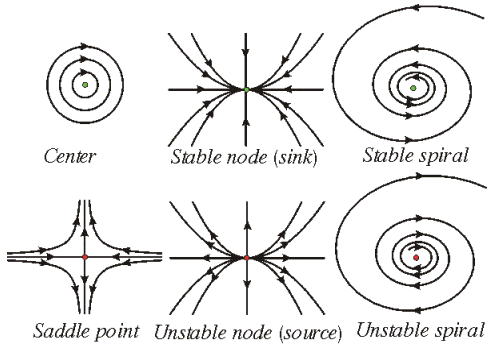



Center
Stable node (sink)
Stable spiral
Saddle point
Unstable node (source)
Unstable spiral

$$f_i = \frac{dN_i}{dt} \quad J_{ij} = \frac{\partial f_i}{\partial N_j} \quad \mathbf{J} = \begin{bmatrix} J_{ii} & J_{ij} \\ J_{ji} & J_{jj} \end{bmatrix}$$

Characteristic equation: $\lambda^2 - A_1\lambda + A_2 = 0$ $\quad A_1 = \mathrm{Trace}(\mathbf{J})$ $\quad A_2 = \mathrm{Det}(\mathbf{J})$

Classification of equilibria according to stability properties



Trace(J)

Trace(J)<0

Trace(J)=0

λ_i all have real parts = 0

Center - Neutral stability

Trace(J)>0

Det(J)>0

Det(J)<0

λ have opposite signs

Saddle point (unstable)

Det(J)>0

Det(J)<0

λ have opposite signs

Saddle point (unstable)

λ_i<0 and real $\forall i$

(no imaginary parts)

Stable node

λ_i<0 $\forall i$

(imaginary parts)

Stable focus/spiral

λ_i>0 and real $\forall i$

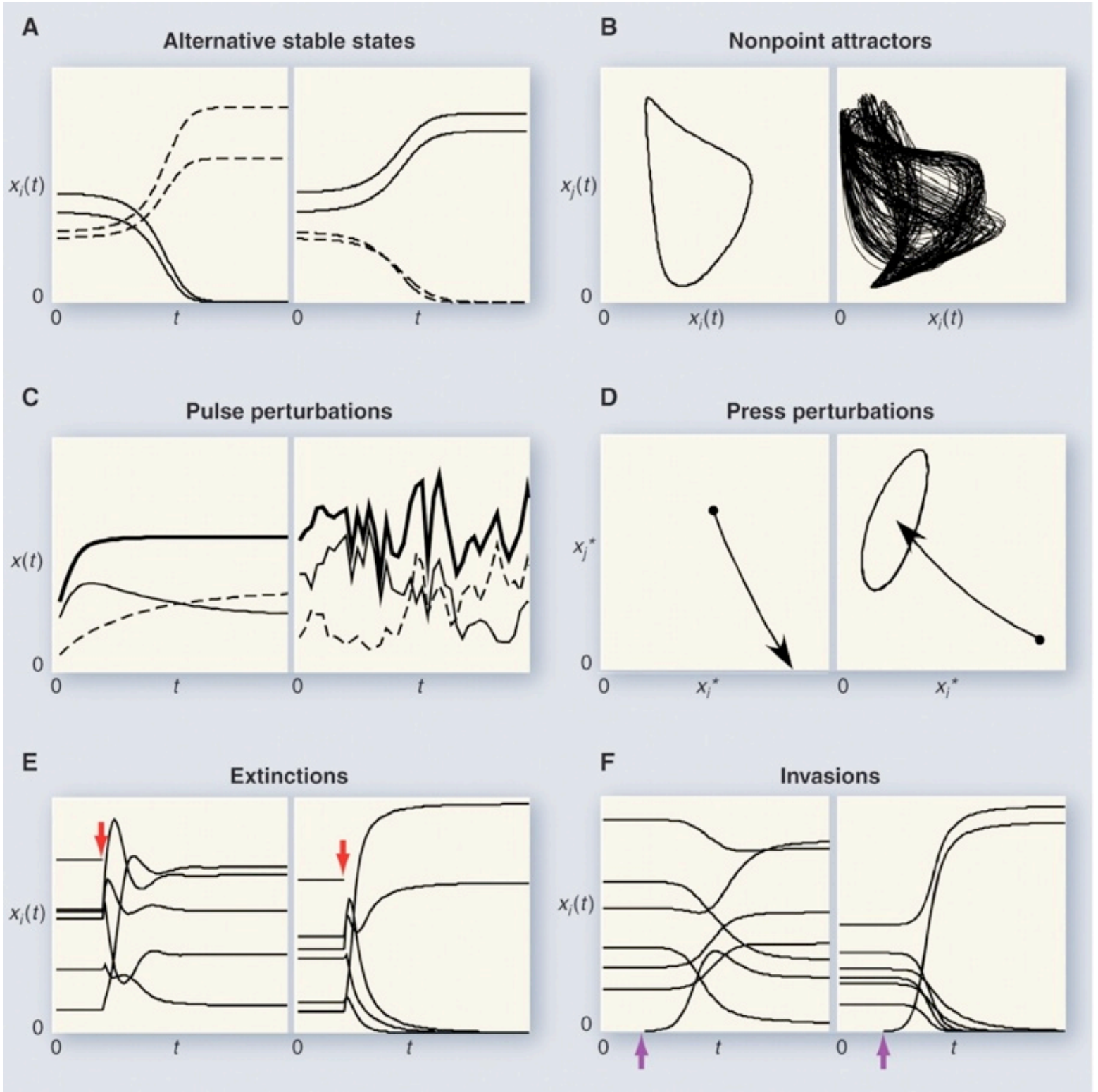
(no imaginary parts)

Unstable node

λ_i>0 $\forall i$

(imaginary parts)

Unstable focus/spiral


A
Alternative stable states
$x_i(t)$
0
0
t
0
t
B
Nonpoint attractors
$x_j(t)$
0
0
$x_i(t)$
0
$x_i(t)$
C
Pulse perturbations
$x(t)$
0
0
t
0
t
D
Press perturbations
x_j^*
0
0
x_i^*
0
x_i^*
E
Extinctions
$x_i(t)$
0
0
t
0
t
F
Invasions
$x_i(t)$
0
0
t
0
t