无标度网络中的长周期同步

易欣欣

神经系统怎样处理时间信息

- 中央时钟？
- 专门计算时间的起搏器？
- 将信息分配给局部回路？
- ？

？ —找文献→ 斑马鱼视顶盖神经回路信息保持时间为20s

？ ✖→ 建立一个随机连接的递归网络

建立一个随机连接的递归网络 → 只能保持数百毫秒

只能保持数百毫秒 ↔ 斑马鱼视顶盖神经回路信息保持时间为20s

时钟计时指导电路有节奏放电

神经系统怎样处理时间信息

中央时钟？专门计算时间的定时器 → 神经回路
- 自我维持同步放电
- 节奏跟外界刺激节奏一致

内在动力就足以产生有节奏同步放电

将信息分配给局部回路？

单个神经元和神经突触的时间常数过短（约10-1000ms）

均匀神经网络

无标度网络结构

斑马[illegible]

信息保持时间为20s

特点：

1.在网络中的大部分节点只和很少节点连接(节点的‘度’很小)，而有极少的节点与非常多的节点连接(节点的‘度’非常高)；

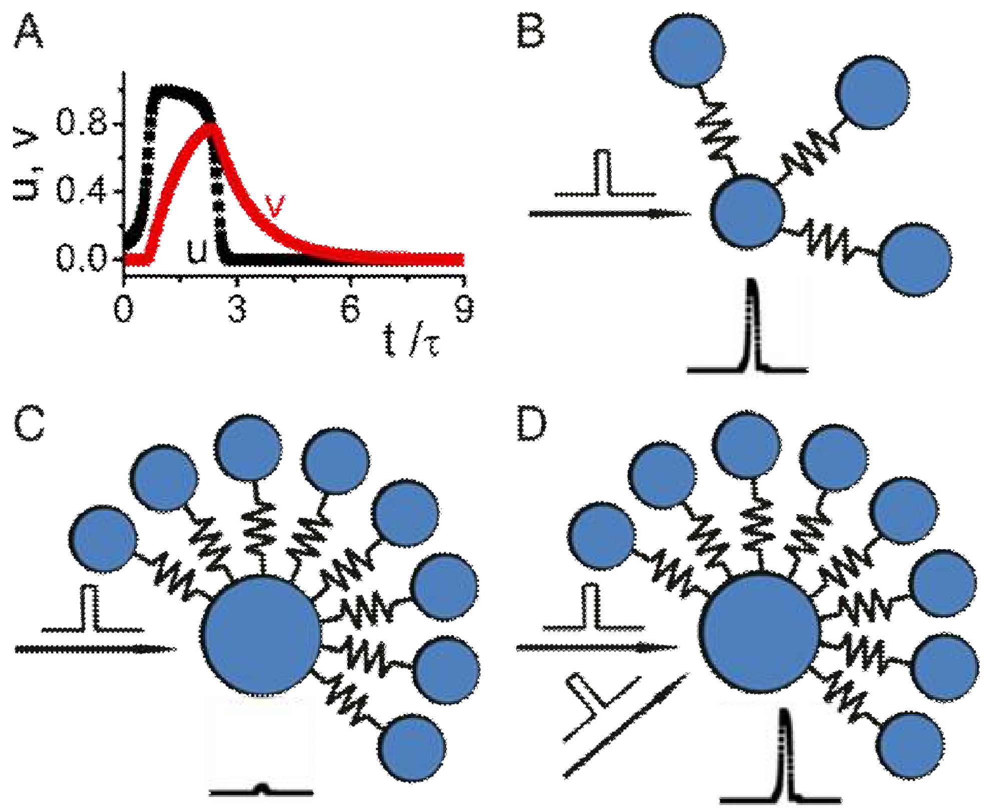
2.激活‘度’高的节点比激活‘度’小的节点困难

单个神经元动态方程：

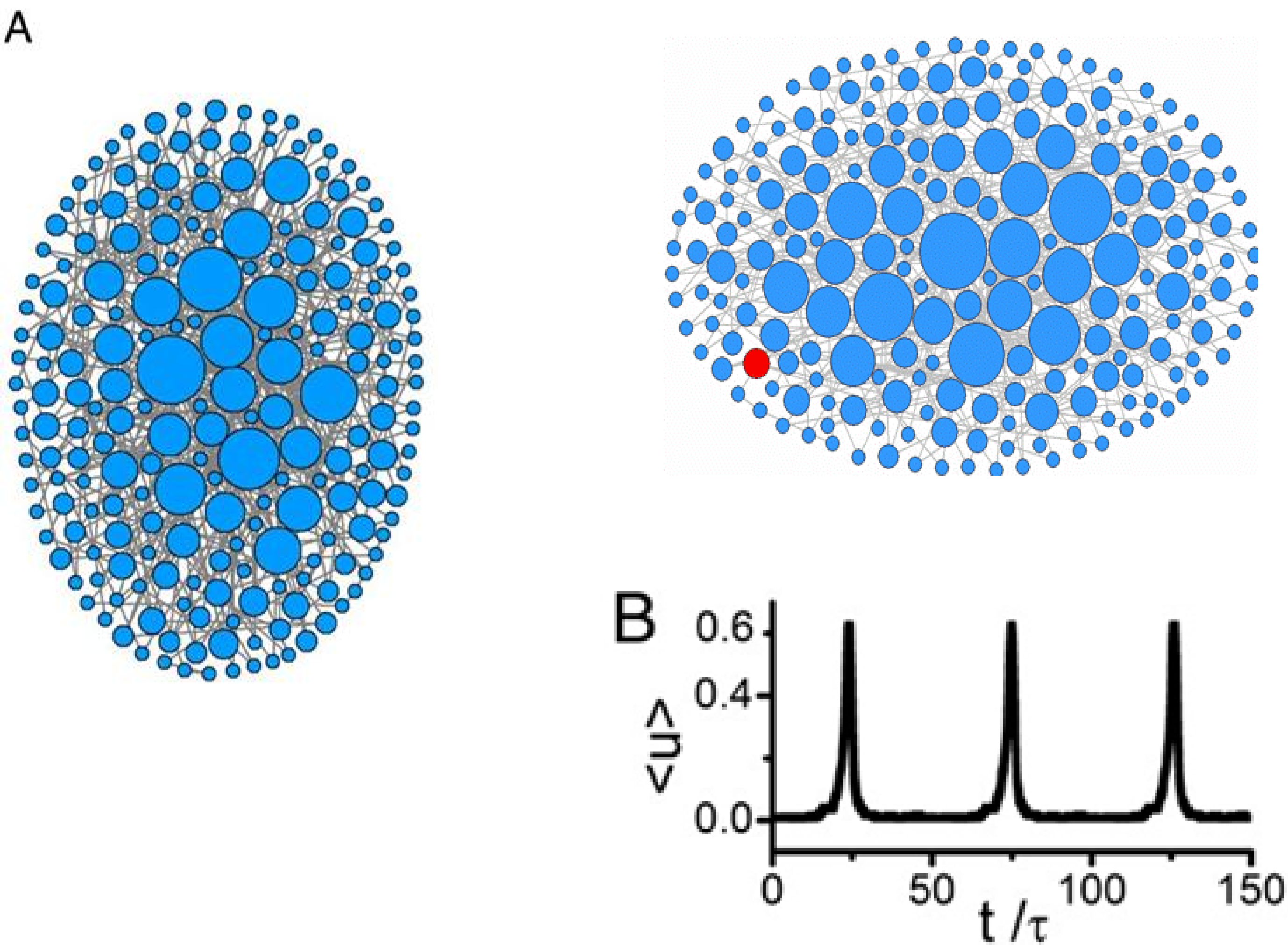
$$\frac{du_i}{dt} = 1\frac{1}{e}u_i(u_i-1)\left(u_i-\frac{v_i+b}{a}\right)+\sum_{j\neq i}^{N}F_{ij}, \quad [1]$$

$$\tau\frac{dv_i}{dt} = f(u_i)-v_i, \quad [2]$$

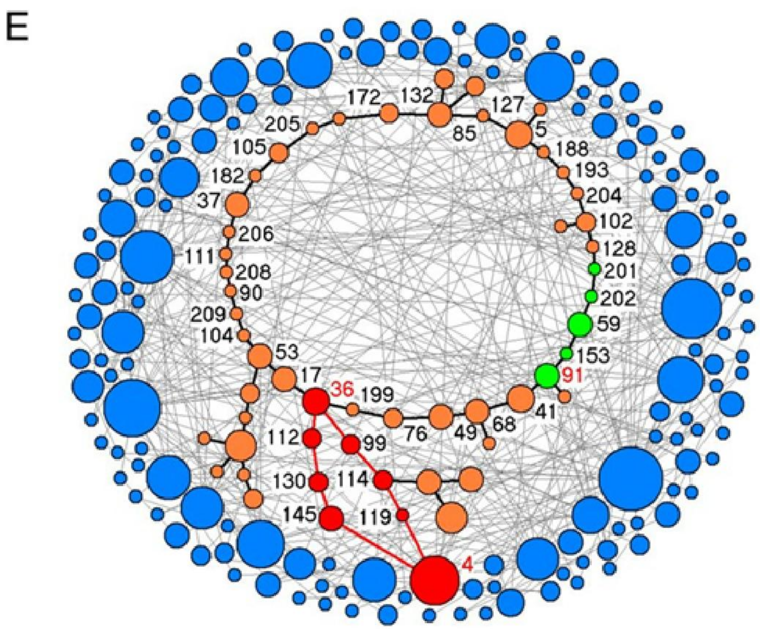
$$f(u_i) = 0.1-6.75u_i(u_i-1)^{\ 2}$$

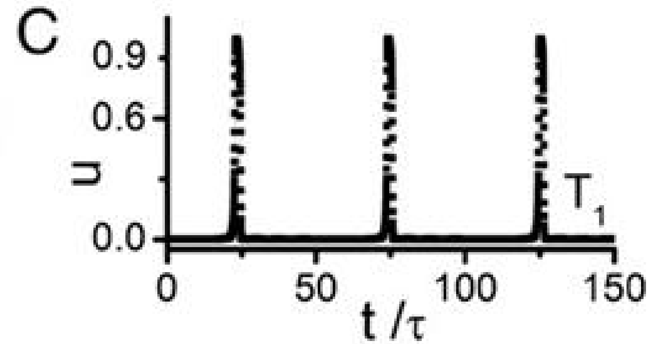


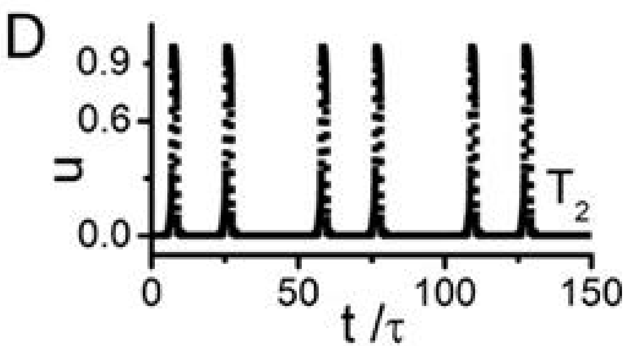
无标度网络中的有节奏的同步放电

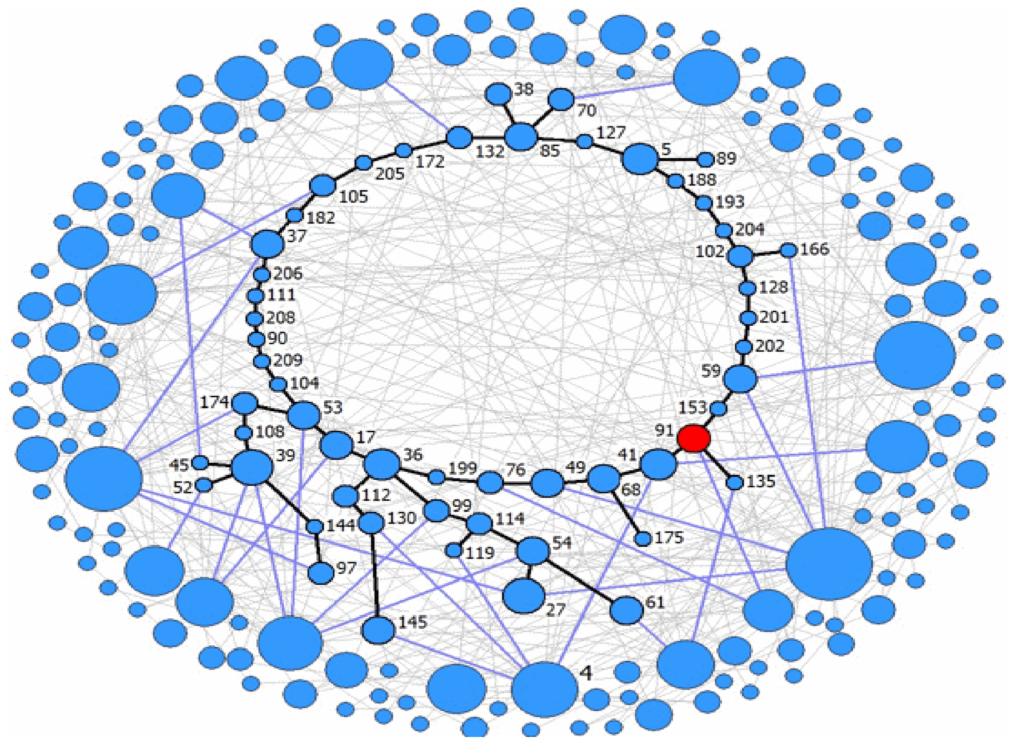


长周期有节奏的同步放电机制

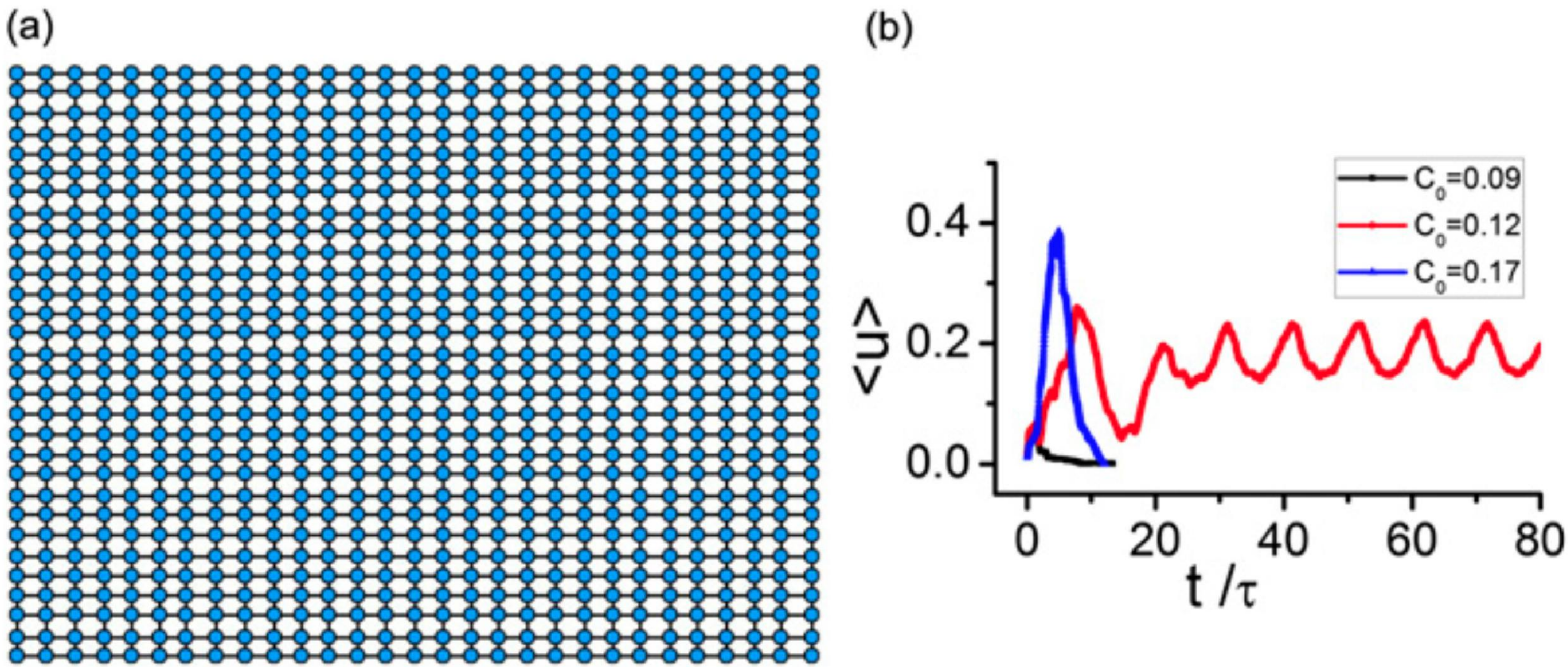








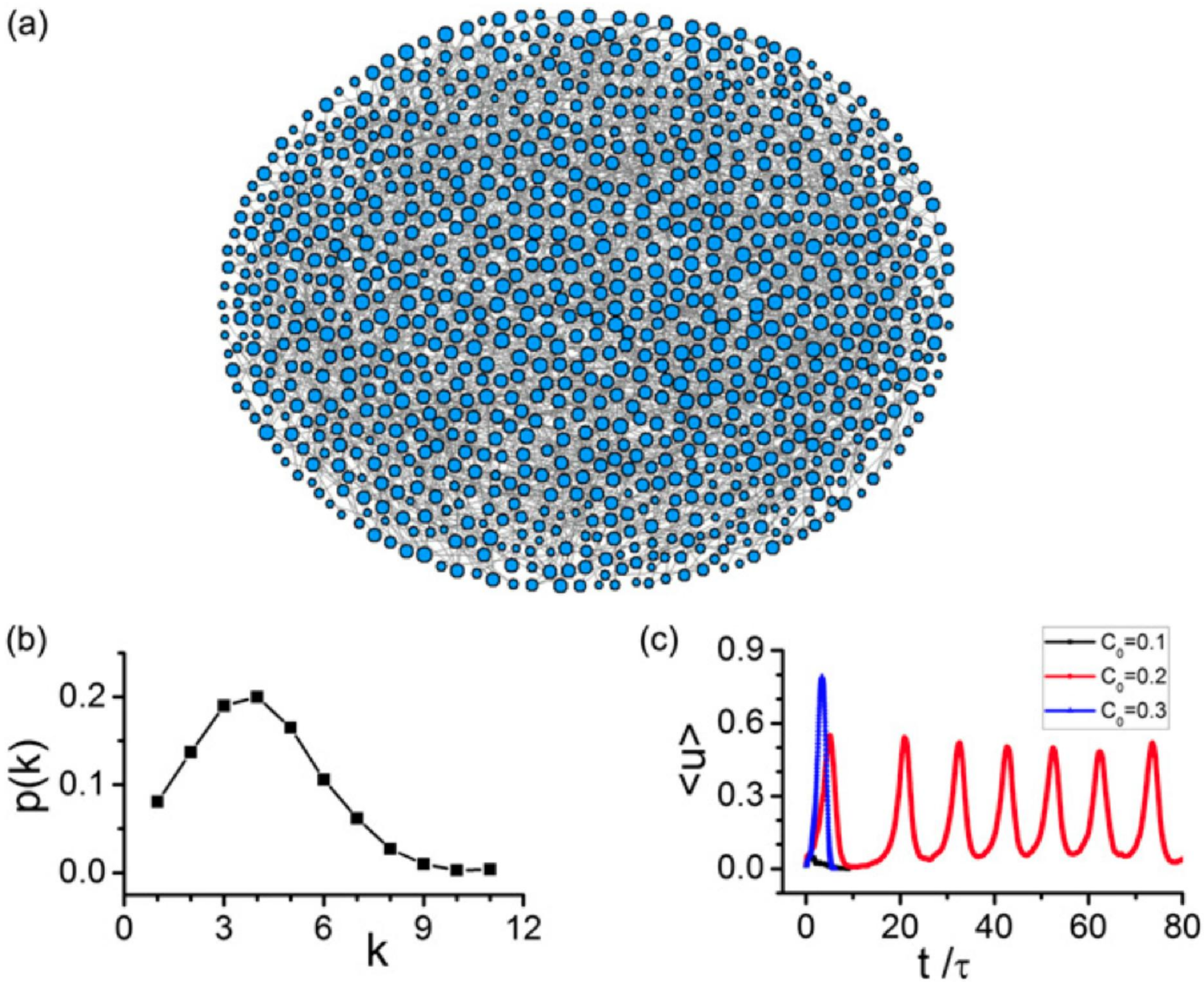
长周期有节奏的同步放电机制



(A) A regular network of 1,000 neurons with connectivity k =4 in 2D space.

(B)Three typical responses of the network to a strong transient stimulation (4% neurons randomly chosen in the network are activated). For weak synaptic strength (the black curve), the network's response is weak and fades away rapidly; for strong synaptic strength (the blue curve), the network displays a strong transient response; and for moderate synaptic strength (the red curve), the network exhibits high-frequency oscillation.

长周期有节奏的同步放电机制

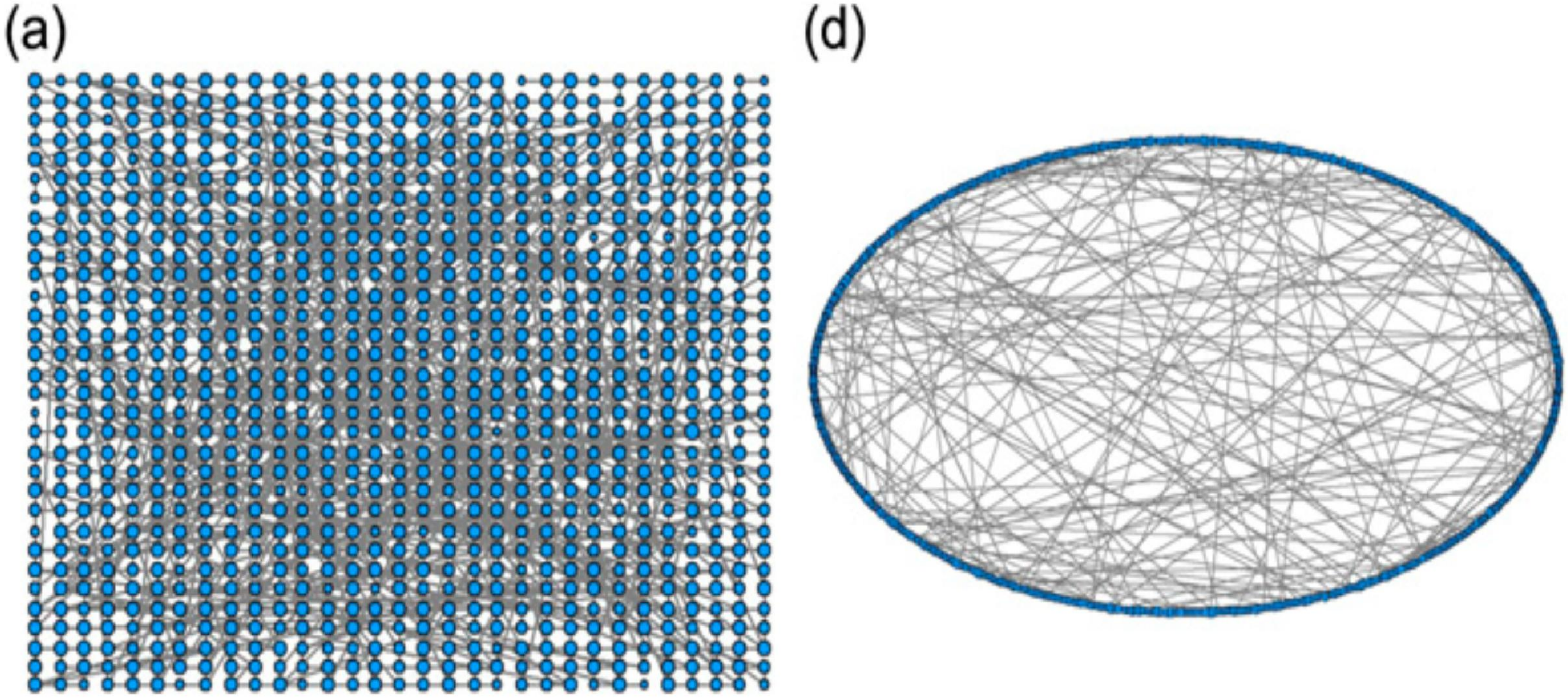


(A) A Erdös-Rényi random network of 1,000 neurons with mean connectivity <k> = 4.

(B) The network connectivity satisfies the Poisson distribution.

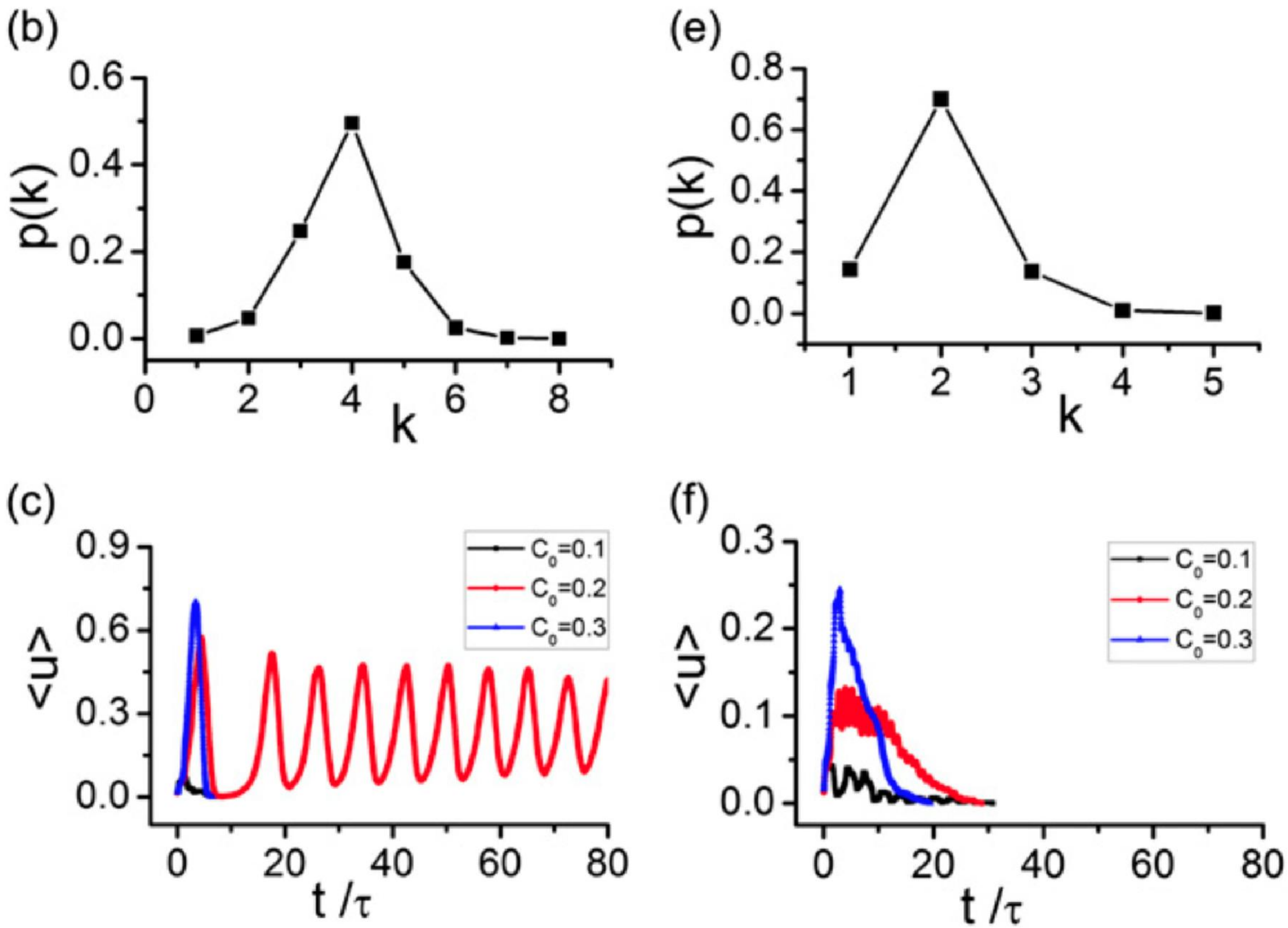
(C) Three typical behaviors of the network in response to an external strong transient stimulation. For weak synaptic strength (the black curve), the network's response is weak and fades away rapidly; for strong synaptic strength (the blue curve), the network displays a strong transient response; and for moderate synaptic strength (the red curve), the network exhibits high-frequency oscillation.

长周期有节奏的同步放电机制



(A And D). Two random networks, each of them having 1,000 neurons, are generated by rewiring a 2D regular network and a 1D loop, respectively. The rewiring probability is 20%

长周期有节奏的同步放电机制

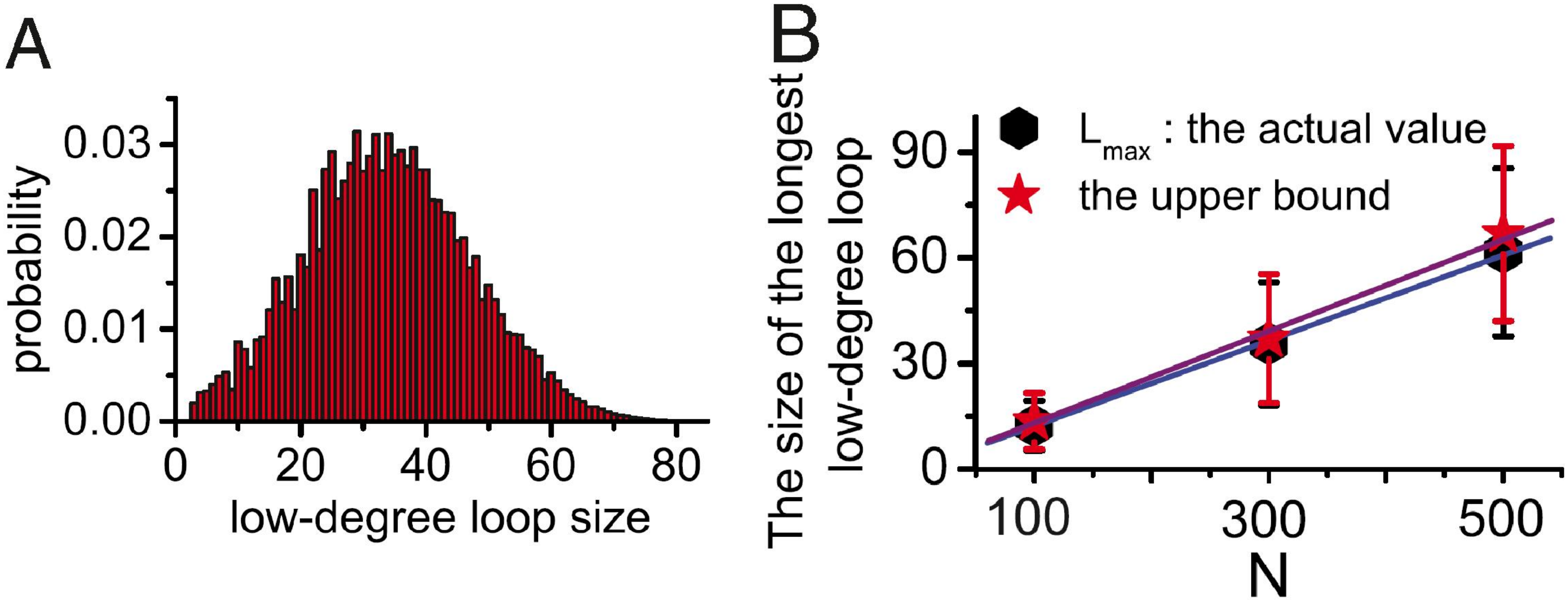


(B and E) .The two networks in A and D have the small-world topology, and the neuronal connections satisfy the Poisson distribution.

(C).Three typical behaviors of the small-world network in A in response to a strong transient stimulation. For weak synaptic strength (the black curve), the network response is weak and fades away rapidly; for strong synaptic strength (the blue cure), the network generates a strong transient response; and for moderate synaptic strength (the red curve), the network oscillates with high frequency.

(F). The behaviors of the network in D in response to a strong transient stimulation with three synaptic strengths. The network only responds transiently.

无标度网络的容纳能力



(A) Distribution of the lengths of low-degree loops in a scale-free network of size N = 300. The result is obtained by averaging 100 randomly generated scale-free networks of the same size.

(B) Length of the longest low-degree loop vs. the number of neurons in a network. Actual values are obtained through extensively searching all loops in each network, and the upper bounds are calculated theoretically (Fig. S4). For each data point, the result is obtained by averaging over 100 randomly generated scale-free networks of the same size.

无标度网络的容纳能力

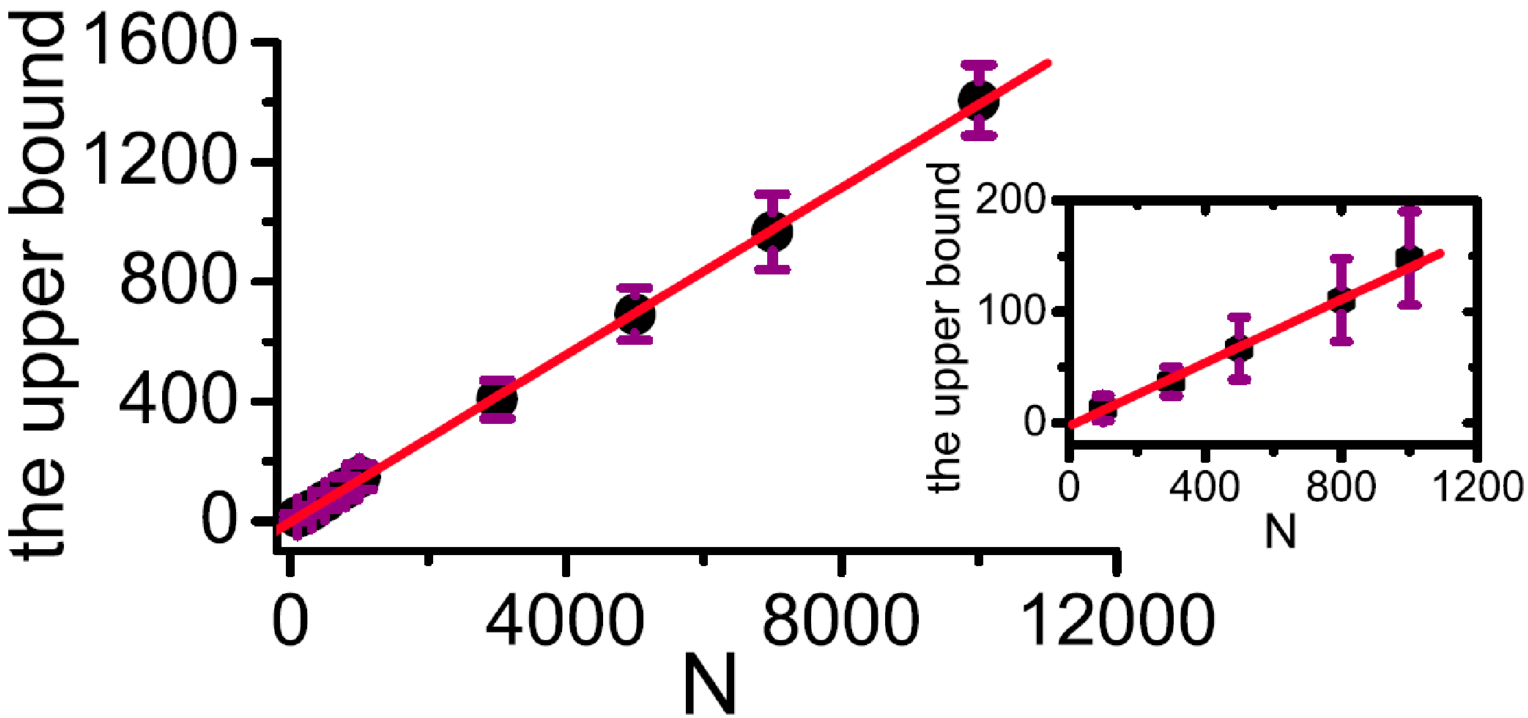
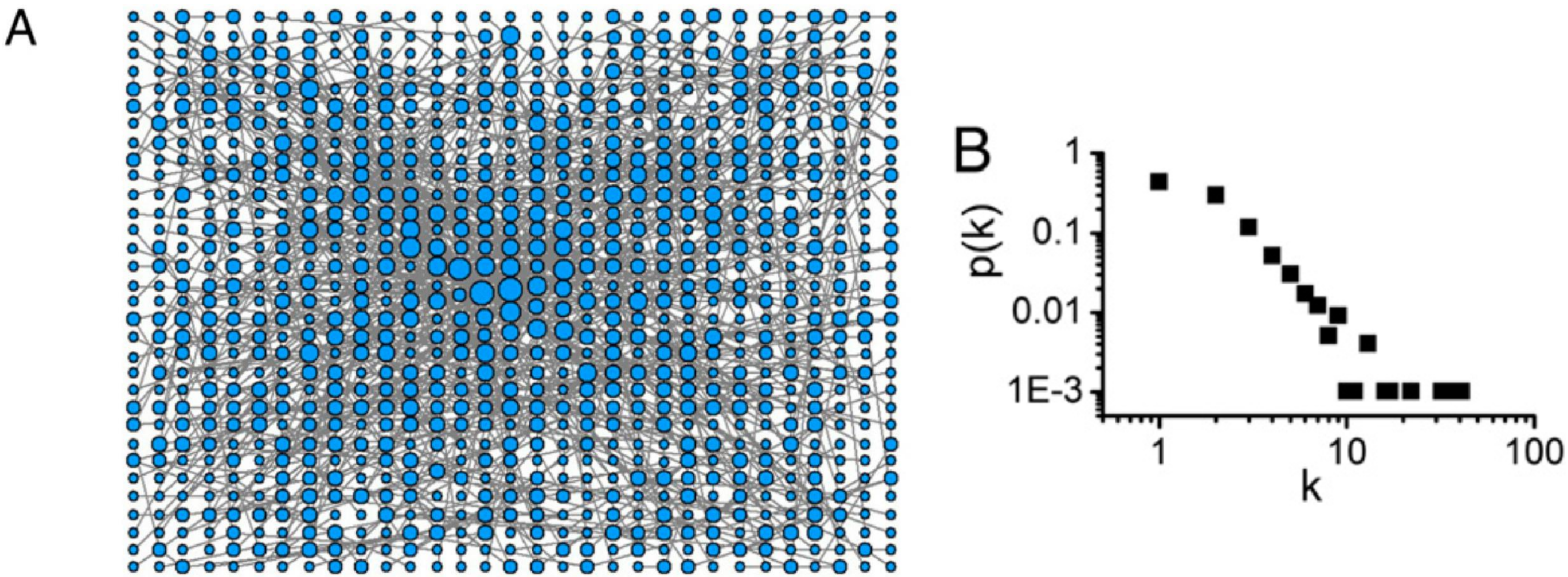


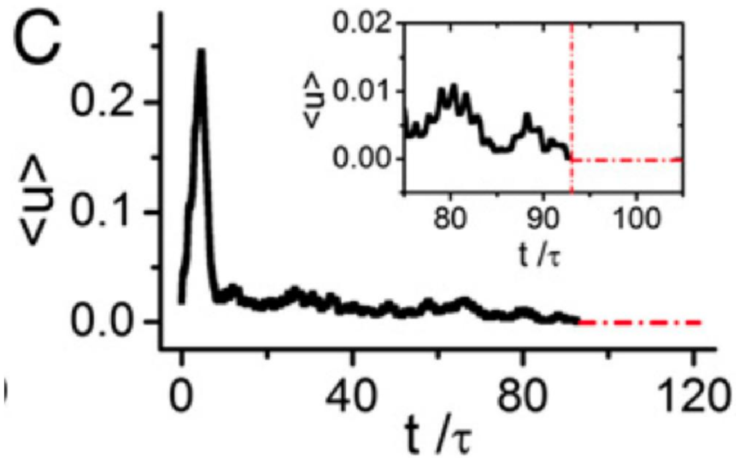
Fig. S4. The upper bound of the longest low-degree loop vs. the network size. The length of the longest loop $L_{\max}$ increases linearly with the number of neurons N in the network. Fitted by a linear curve, it $L_{\max} \approx 0.13983N - 3.05$. For each data point, the result is obtained by averaging over 100 randomly generalized scale-free networks of the same size. (Inset) Result for N <1,000 with a fine scale.

同步外部输入的节奏

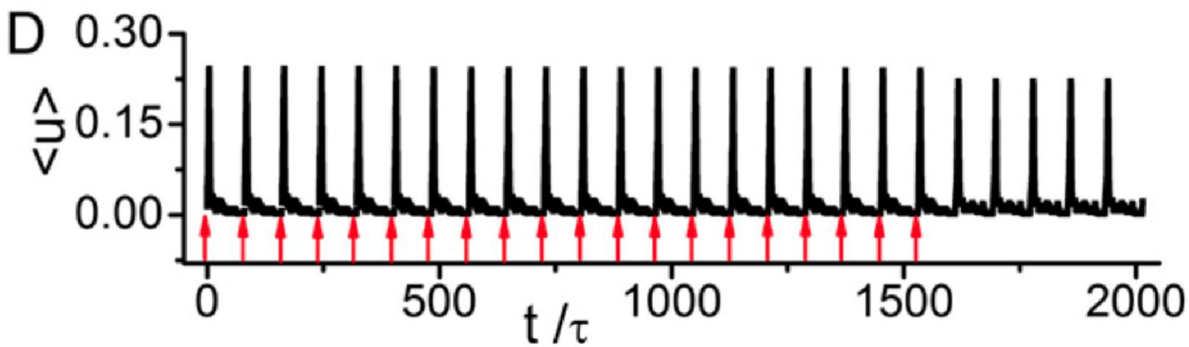


(A) A scale-free network of 1,000 neurons in 2D space, in which neurons tend to have higher connectivity locally.
(B) The connectivity distribution of the network, which satisfies the power law, with γ = 1.95.

同步外部输入的节奏

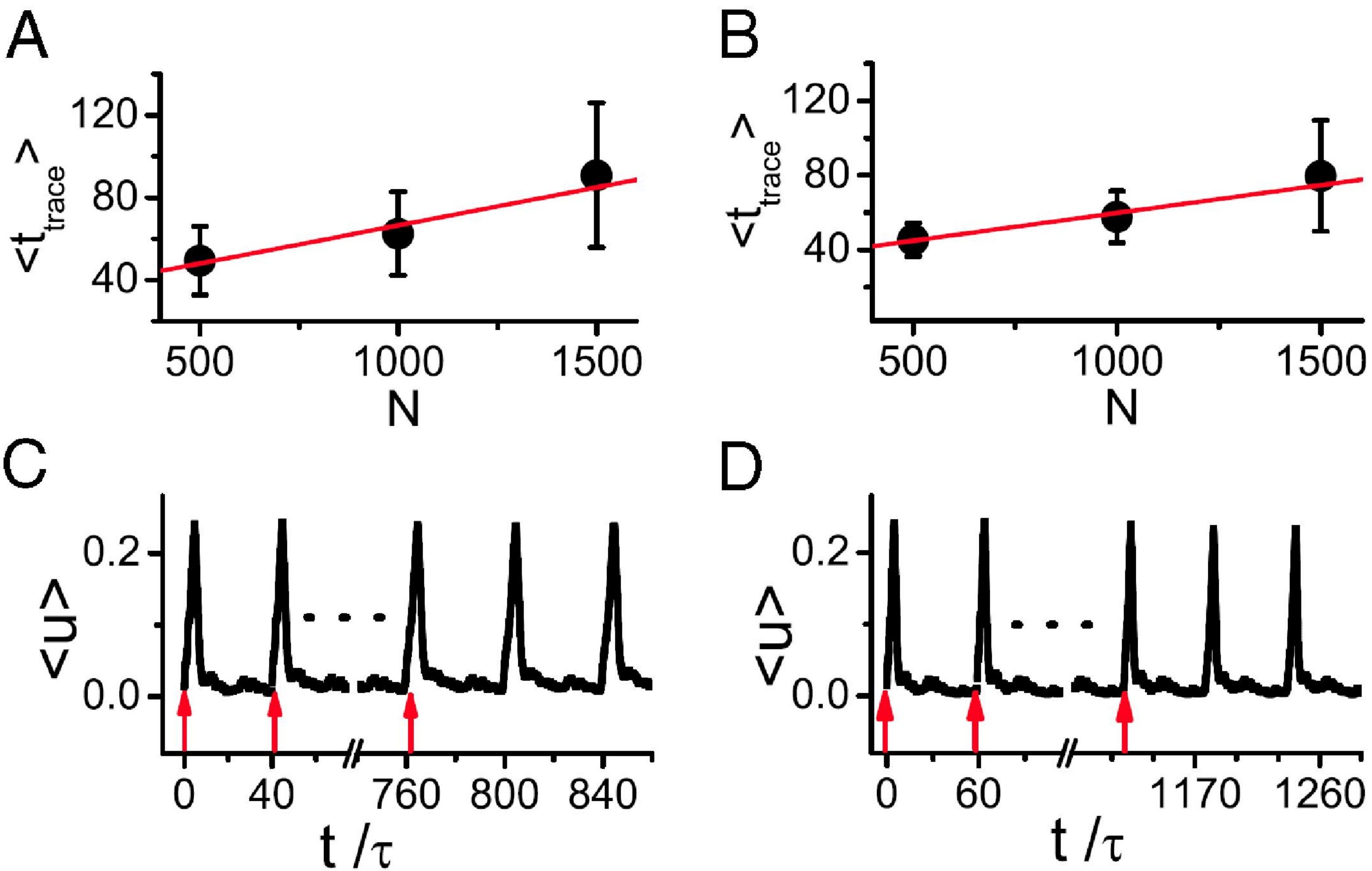


(C)The network can retain residual activity elicited by a transient strong stimulation for more than 90τ. (Inset) Network activity around 90τ. This residue activity serves as a memory trace of the stimulation. Electrical synapses are used. Parameters are the same as in Fig. 1 A and B.



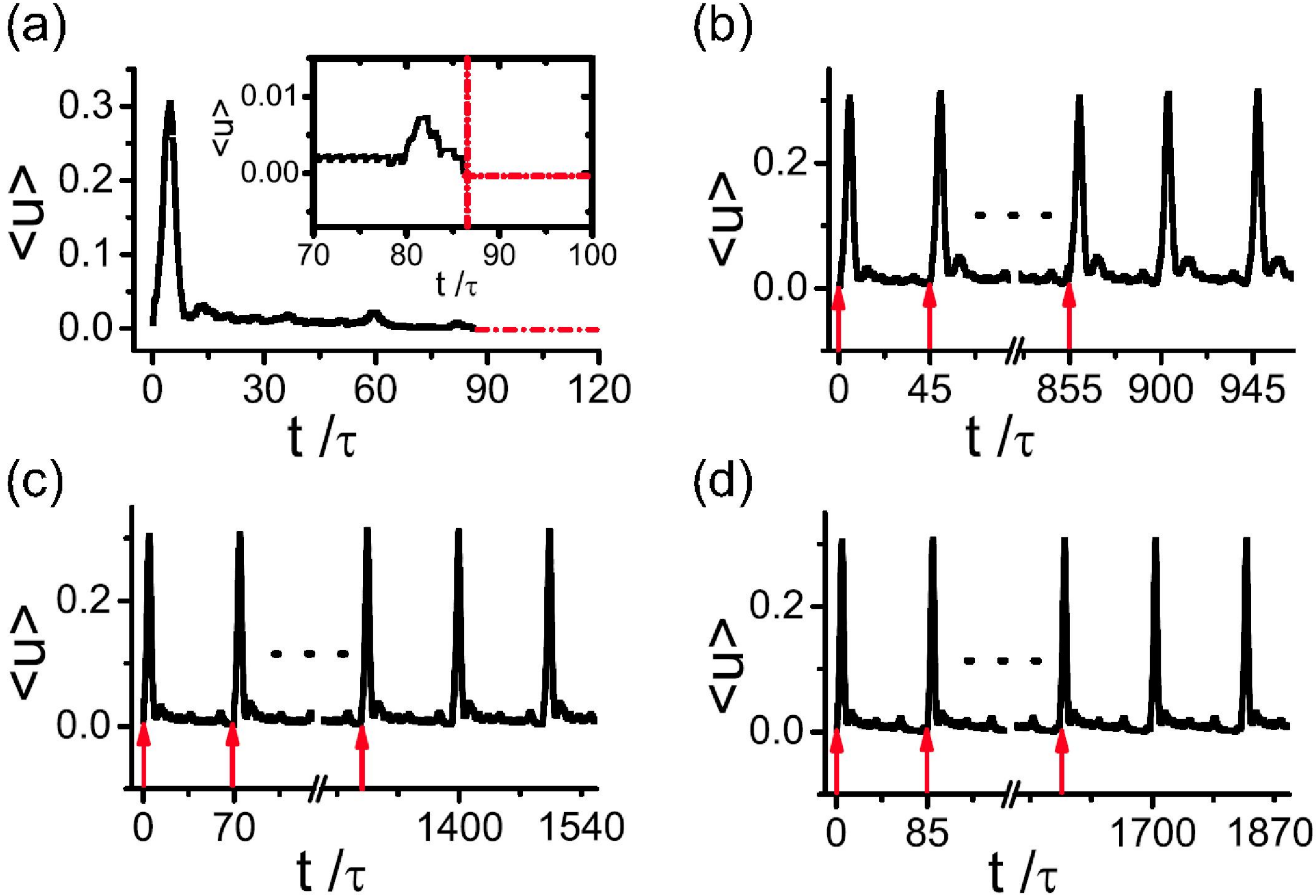
(D) Network learns to generate rhythmic synchronous firing with a period of 80τ after an external stimulation is presented repeatedly for 20 times.

同步外部输入的节奏



A
B
C
D
<t_trace>
120
80
40
500
1000
1500
N
<u>
0.2
0.0
0
40
760
800
840
60
1170
1260
t /τ

同步外部输入的节奏



(a)
(b)
(c)
(d)
<u>
0.3
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80
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855
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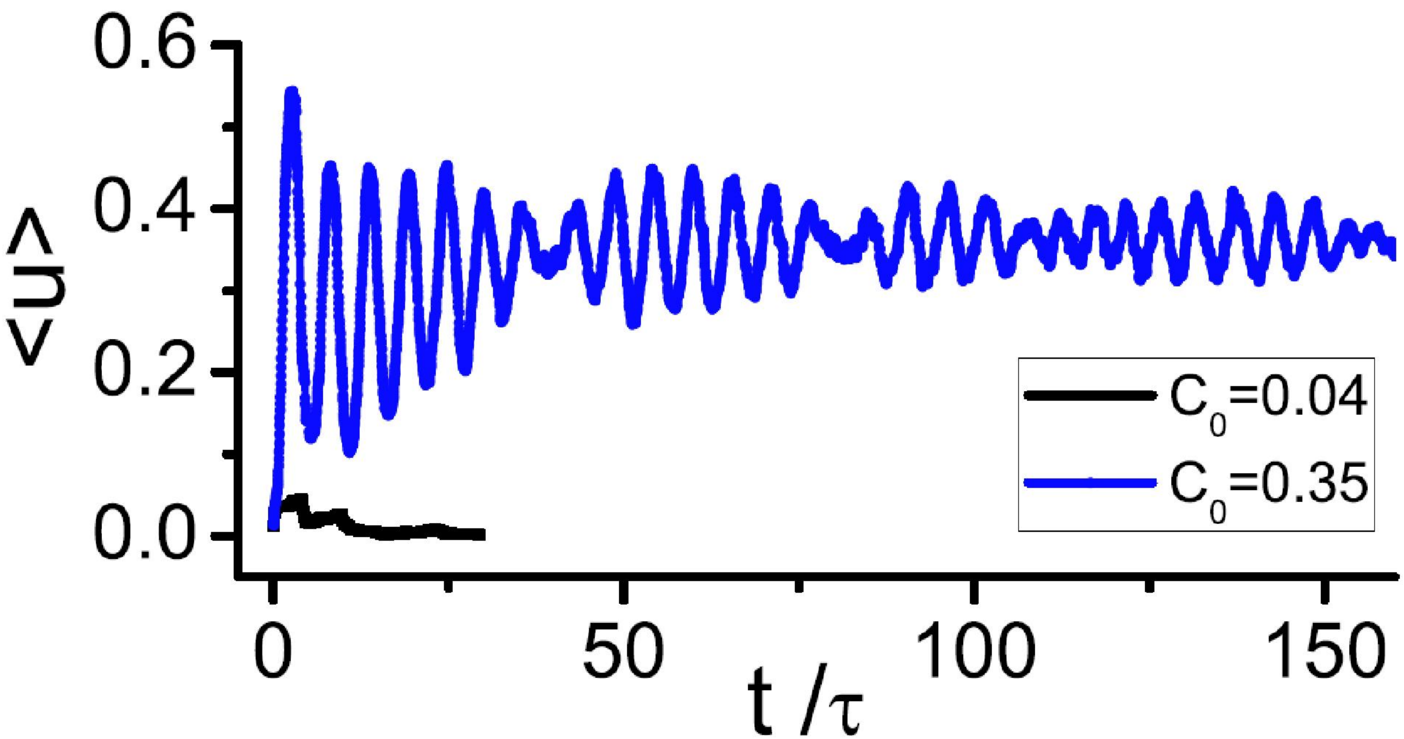
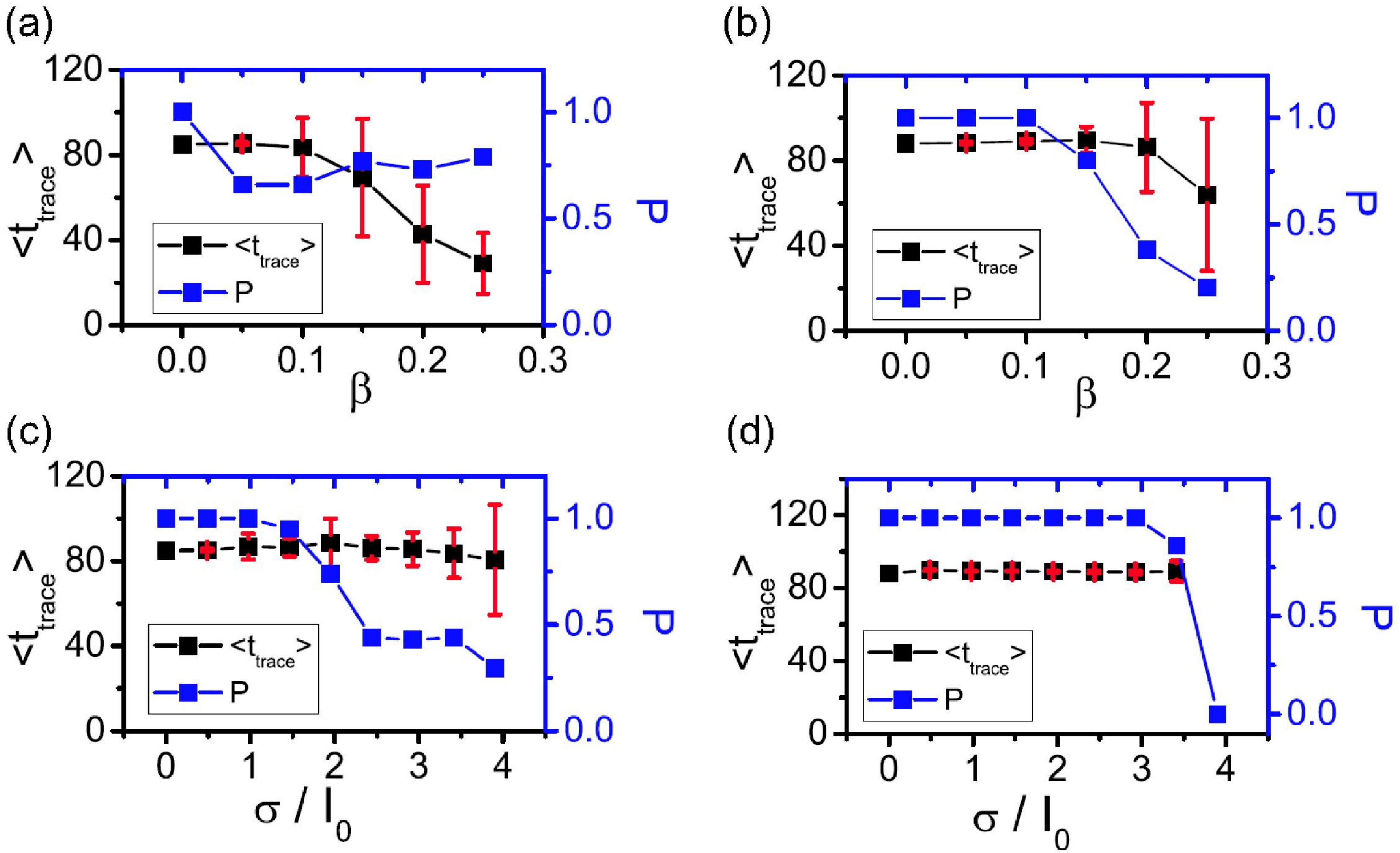
1400
1540
85
1700
1870



Two typical behaviors of the scale-free network in Fig. 4A with homogenous chemical synapses in response to a strong transient stimulation. For weak synaptic strength (the black curve), the network response is weak and fades rapidly; for strong synaptic strength (the blue curve), the network oscillates with high frequency.


(a)
(b)
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(d)
120
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1.0
0.5
0.0
0.0
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0.2
0.3
0
1
2
3
4
β
σ / l0
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P

结论：

在本研究中

- 这个无标度网络模型能够产生和保持长周期有节奏同步放电；
- 这个无标度网络模型有一定的容纳强度；

即：该网络具有无标度的拓扑结构以及低水平环和各种规格的链，这使得神经网络有了能够处理广范围有节奏输入的能力。

- 这个无标度网络模型有一定的学习能力，可以学习外部输入的节奏。

即：在有节奏的外部输入的存在下，神经系统从它的库中选择和输入节奏一致的低水平环，这种匹配操作能够通过学习过程实现。

启发：

网络模型是个好东西，可以将我们生活中的恶好多东西数据化，模拟出来，很好的解释其中的原理。学好了可以解决好多问题，节约好多成本。真是百利无一害啊~

结束！