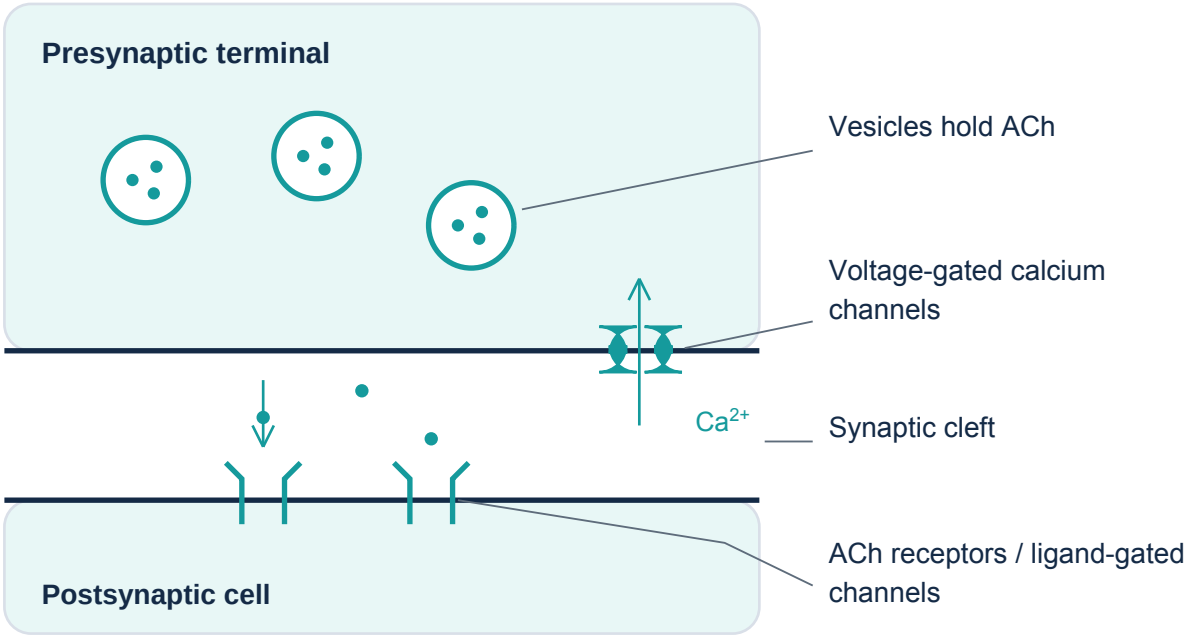
A chemical bridge between cells

A cholinergic synapse uses acetylcholine (ACh) as its neurotransmitter. Here, an excitatory synapse converts an arriving electrical signal into a chemical signal and back again.

1. RECOGNISE THE STRUCTURES



Teal dots = ACh molecules. Membrane patches are enlarged; not to scale.

2. THE RELEASE SIDE

The presynaptic terminal contains ACh-filled vesicles and mitochondria that supply ATP for cellular processes. An arriving action potential opens voltage-gated Ca^{2+} channels. Calcium entry triggers vesicle fusion with the presynaptic membrane and exocytosis.

3. THE RECEIVING SIDE

ACh diffuses across the cleft and binds specific postsynaptic receptors. In this excitatory example, ligand-gated cation channels open. At resting voltage, the net inward positive current depolarises the receiving membrane; Na^{+} entry is important.

Synapse structure and release: OpenStax, Biology 2e 35.2.
Receptors and cholinergic signalling: OpenStax, A&P 2e 12.5.

Scope: Cambridge Biology 9700, section 15.1, outcomes 9-10, p. 39.

Transmit, then reset

Keep the events in order: voltage change, calcium entry, transmitter release, diffusion, receptor binding and a new electrical response.

1. FOLLOW ONE SIGNAL

A. Arrive	The action potential depolarises the presynaptic terminal.
B. Release	Ca^{2+} enters; vesicles fuse and release ACh by exocytosis.
C. Cross	ACh molecules diffuse across the cleft; the action potential itself does not.
D. Respond	ACh opens receptor channels. If depolarisation reaches threshold at the trigger region, voltage-gated channels generate a new action potential.

2. REMOVE THE TRANSMITTER

Acetylcholinesterase (AChE) hydrolyses ACh into choline and acetate. This stops repeated receptor activation. Choline is taken back into the presynaptic terminal, used to synthesise more ACh, and the transmitter is packaged into vesicles.

3. WHY TRANSMISSION HAS A DIRECTION

At this chemical synapse, the release machinery is presynaptic and the receiving receptors are postsynaptic. This asymmetric arrangement produces one-way transmission. Release, diffusion and receptor activation also introduce a short synaptic delay.

Key distinction: a local postsynaptic potential is graded. It does not guarantee an all-or-nothing action potential in the receiving neurone.

Chemical transmission and delay: OpenStax, Biology 2e 35.2.
Postsynaptic responses and signal termination: OpenStax, A&P 2e 12.5.

Scope: Cambridge Biology 9700, section 15.1, outcomes 9-10, p. 39.

From a motor neurone to a muscle

A neuromuscular junction is a cholinergic synapse between a motor neurone and a skeletal muscle fibre. Its specialised postsynaptic region is the motor end plate.

1. EXCITE THE MUSCLE MEMBRANE

ACh activates nicotinic receptors at the folded motor end plate. The resulting end-plate potential normally reaches threshold and opens nearby voltage-gated Na^+ channels. A muscle action potential then spreads along the sarcolemma, the muscle cell surface membrane.

2. CARRY THE SIGNAL INTO THE FIBRE

Sarcolemma
Action potential spreads

→

T-tubules
Signal travels inward

→

SR
Calcium is released

T-tubules are inward folds of the sarcolemma, not calcium stores. Their depolarisation triggers Ca^{2+} release from the sarcoplasmic reticulum (SR) into the sarcoplasm. Calcium binds troponin, allowing the contractile machinery to act.

3. END THE RESPONSE

AChE removes ACh at the junction. When stimulation ends, ATP-driven pumps return Ca^{2+} to the SR. As cytoplasmic calcium falls, the regulatory proteins block myosin-binding sites again, allowing the muscle to relax.

4. CALCIUM HAS TWO DIFFERENT JOBS

Nerve terminal: Ca^{2+} enters from outside and triggers ACh release.
Muscle fibre: Ca^{2+} leaves the SR and activates contraction.

Motor end plate and T-tubules: OpenStax, A&P 2e 10.2.
Calcium, contraction and relaxation: OpenStax, A&P 2e 10.3.

Scope: Cambridge Biology 9700, section 15.1, outcomes 9-10, p. 39.