SUPPLEMENTARY INFORMATION

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Supplementary Discussion

Different PNs have differential sensitivity to the rate of temperature change. Behavioral experiments in both *Drosophila* and mammals indicate that thermal perception depends partly on absolute temperature, and partly on the rate of temperature change[37,38]. It is therefore interesting that we found some neurons that adapt slowly to temperature changes, and others that adapt rapidly (compare e.g., the fast-cool-PNs and the slow-cool-PNs, Figure 1). In other sensory systems, adaptation is often the hallmark of a highly sensitive system, because it can shift the dynamic range of a neuron to match the ambient environment[39]. In this regard, it is notable that the most strongly adapting PNs are also among the most sensitive to small temperature changes (Figure 1).

Behavioral effects of thermoreceptor mutations depend on rates of temperature change. Previous work showed that the *Gr28b.d* pathway is important for normal behavioral responses to temperature increases measuring ~10ºC over tens of seconds[38]. This is compatible with our conclusion that the *Gr28b.d* pathway makes a substantial contribution to warm-PN responses when the rate of warming is ~1ºC/s. When warming is faster, we find that the cool pathway input to warm-PNs becomes more important. Behavioral responses to warming on even slower timescales (~10ºC over 30 min) depend instead on a distinct thermosensory cell located inside the brain[38,40].

Excitatory input from cool peripheral cells onto warm-PNs. It is puzzling that the warm-PNs receive excitation from the cool pathway, in addition to receiving crossover inhibition from the cool pathway. It is worth noting that many central sensory neurons receive excitation and inhibition driven by the same stimuli – i.e., co-modulated or "balanced" excitation and inhibition[41]. In theoretical models, a balance of this type can allow neural networks to respond to stimuli more rapidly and sensitively[42].

Whatever its function, this circuit motif is reminiscent of circuits in the mammalian spinal cord. In the spinal cord, some neurons in the pain pathway receive both excitation and inhibition from mechanosensory pathways, and therefore the mechanosensory inputs to these neurons are normally masked, analogous to the way that cooling-evoked excitation to the warm-PNs is normally masked by cooling-evoked inhibition. Some pathological states reduce inhibition from mechanosensory pathways onto these pain-pathway neurons, causing innocuous mechanical stimuli to be perceived as painful[43,44]. Although this circuit is clinically important, its normal function is not understood. The relative simplicity of the *Drosophila* thermosensory processing circuit makes it a useful model for understanding the function of neural circuits where latent inputs are masked by co-tuned inhibition.

Circuit diagrams. In summarizing our results, we have drawn circuit diagrams with the smallest number of synapses needed to explain our data. However, some of the connections which we have schematized as direct connections may actually be indirect (polysynaptic). Our aim here is to map the functional connectivity from peripheral neurons onto central neurons, but the underlying anatomical connectivity may be more complex.

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