

Adipose Tissue

White and brown adipose tissue

Endocrine signalling, energy homeostasis and inflammation

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Learning objectives

- Distinguish the physiological roles of white and brown adipose tissue.
- Explain how adipocyte-derived leptin and adiponectin influence energy balance.
- Connect adipose-derived inflammatory mediators with obesity-associated systemic inflammation.
- Integrate adipose, hypothalamic and immune pathways in clinicopathologic scenarios.

Adipose tissue is a functional organ

Energy reservoir

Fat stores convey information about available energy.

Endocrine tissue

Adipocytes release leptin, adiponectin and other mediators.

Thermogenic tissue

Brown adipose tissue converts energy into heat.

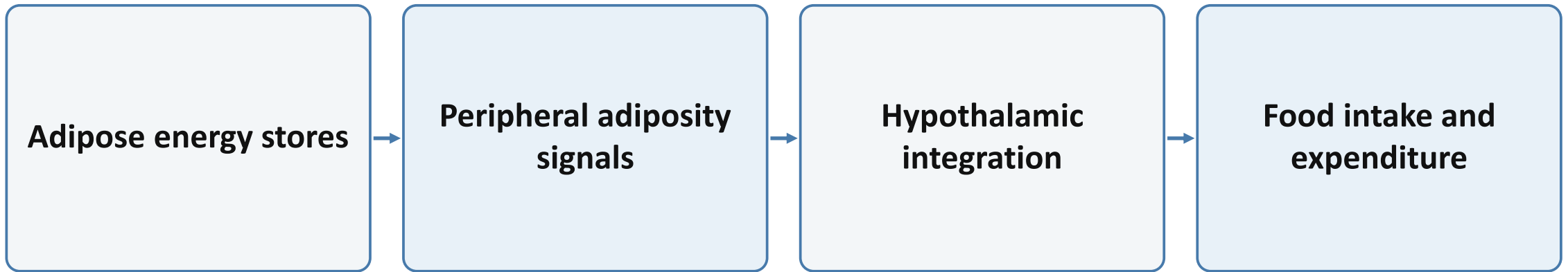
Immune interface

Cytokines and immune cells influence adipose function.

Two adipose tissues, two primary functions

Feature	White adipose tissue	Brown adipose tissue
Key role	Energy storage and endocrine signalling	Energy expenditure as heat
Mediators / mechanism	Leptin, adiponectin, cytokines, chemokines	Nonshivering thermogenesis
Clinical context	Metabolic and inflammatory responses	Energy balance and heat production

Energy storage and energy balance are coupled



Fat stores are not inert: Changing energy reserves alter the signals received by the brain.

Fat quantity and fat distribution are distinct

Total adiposity

Body mass index is widely used as a practical measure of excess body weight.

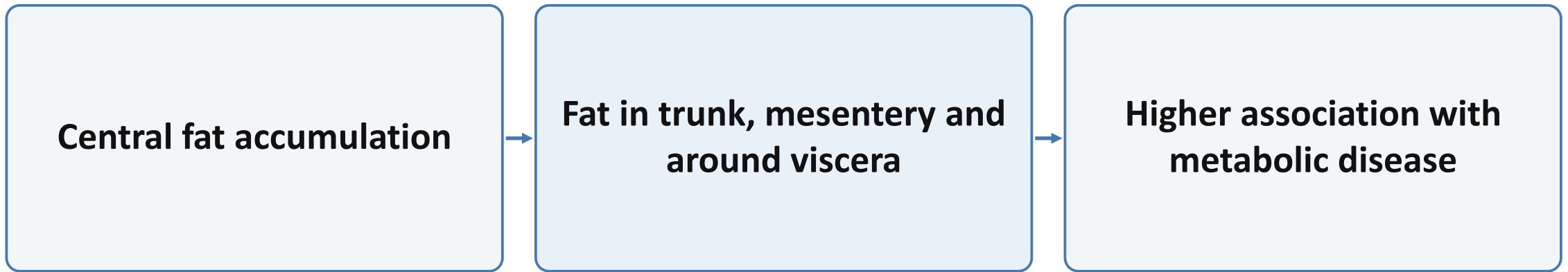
BMI does not identify the anatomical distribution of fat.

Fat distribution

The textbook distinguishes central/visceral accumulation from subcutaneous accumulation.

Visceral predominance is associated with greater disease risk.

Visceral adipose tissue has greater risk association



The anatomical pattern of excess adiposity can matter beyond its overall quantity.

Body weight depends on intake and expenditure

Energy intake

Eating behavior is regulated by neural and hormonal inputs.

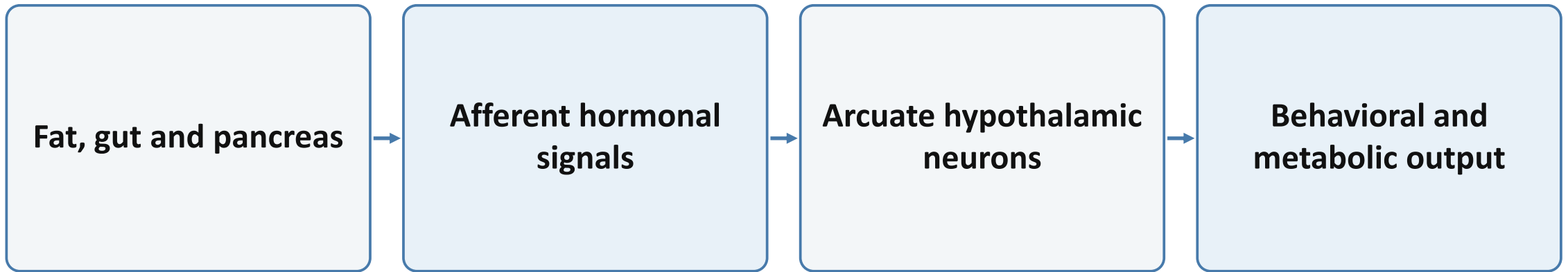
Anabolic circuits favor food intake.

Energy expenditure

Catabolic circuits reduce intake and raise expenditure.

The balance of the two circuits helps stabilize body weight.

The hypothalamus integrates peripheral information



The central processing system interprets signals about nutrient availability and body energy stores.

The adipose-derived endocrine signal: Leptin

Production

Leptin is secreted by adipocytes.

Input variable

Secretion tracks the adequacy of fat stores.

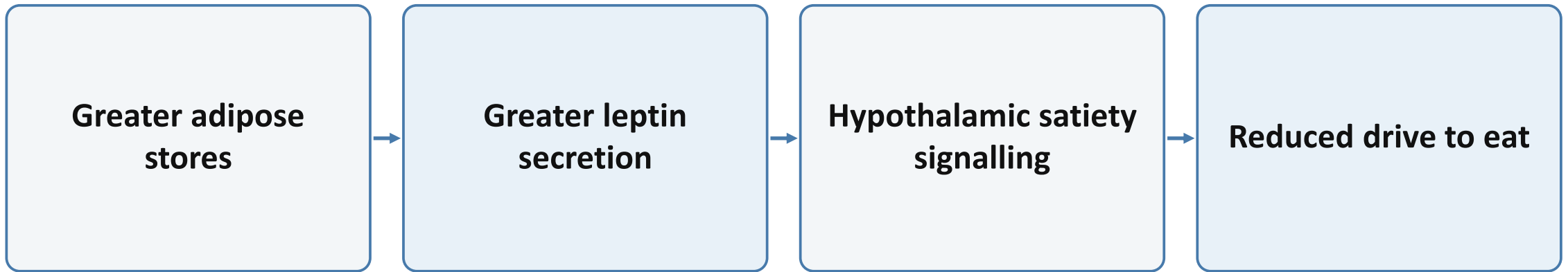
Target

The hormone acts on hypothalamic circuits.

Net function

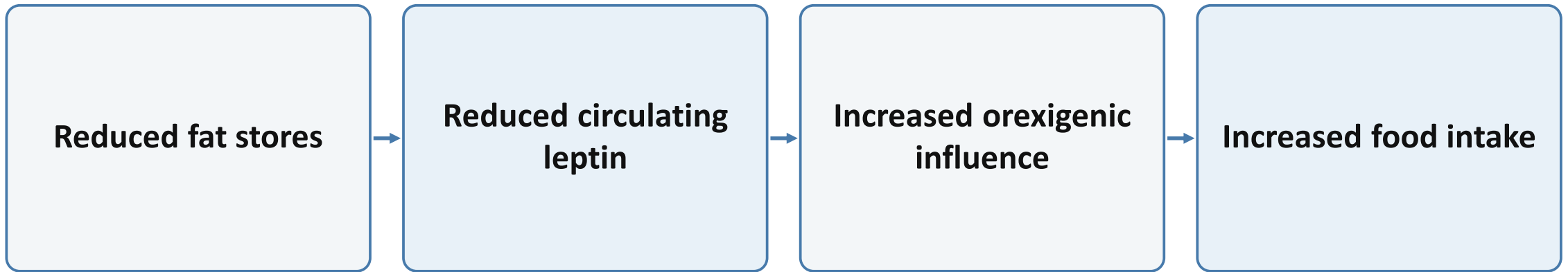
It restrains food intake and facilitates energy expenditure.

Leptin output reflects fat stores



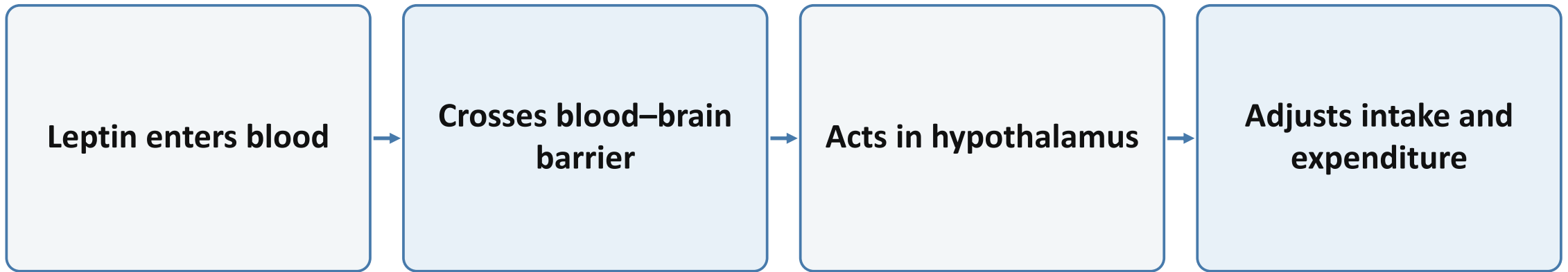
This is a feedback relationship; It does not imply that all obesity states remain leptin-responsive.

Low energy stores reduce leptin feedback



The response favors restoration of energy reserves during an energy deficit.

Leptin acts beyond the adipocyte



The hypothalamus is the main integrating site.

Two arcuate neuronal populations respond to leptin

POMC / CART neurons

Activated by leptin.

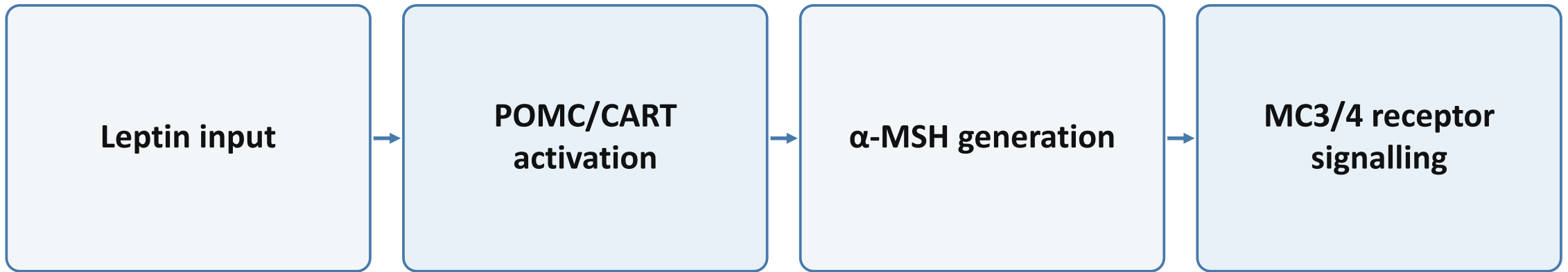
Promote catabolic, anorexigenic output.

NPY / AgRP neurons

Inhibited by leptin.

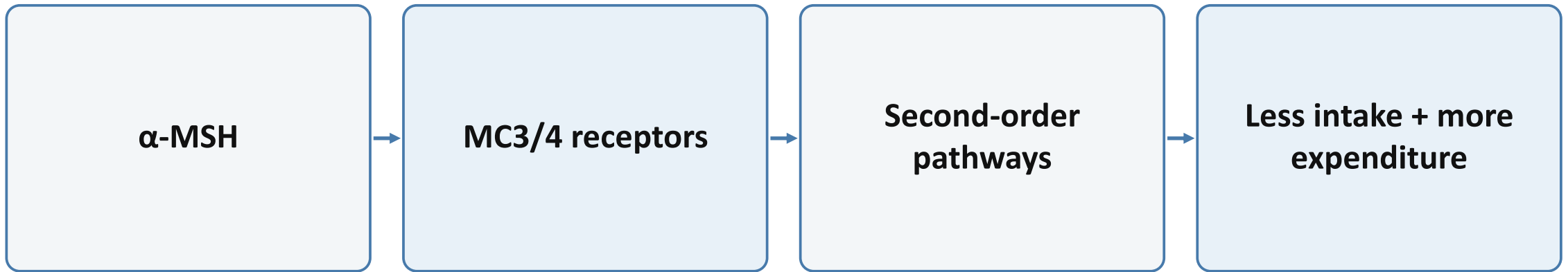
Ordinarily promote feeding and anabolic output.

POMC/CART neurons are the appetite brake



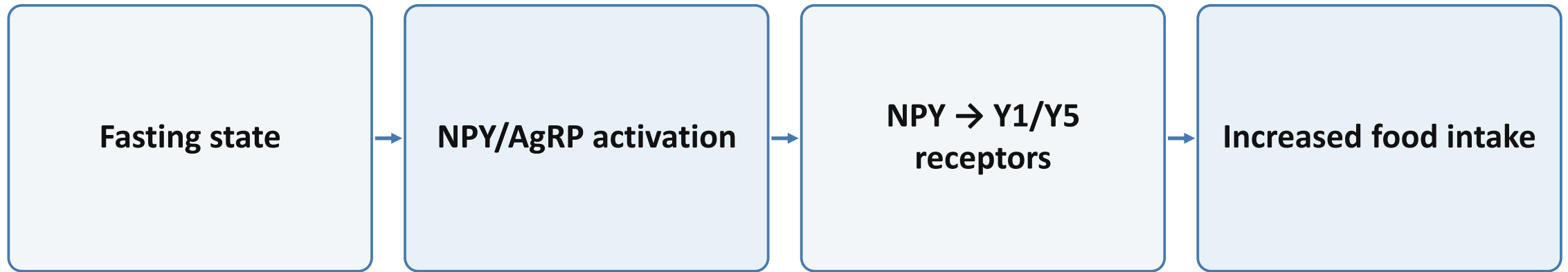
Following food intake, POMC cleavage yields α -melanocyte-stimulating hormone (α -MSH).

Melanocortin signalling produces catabolic output



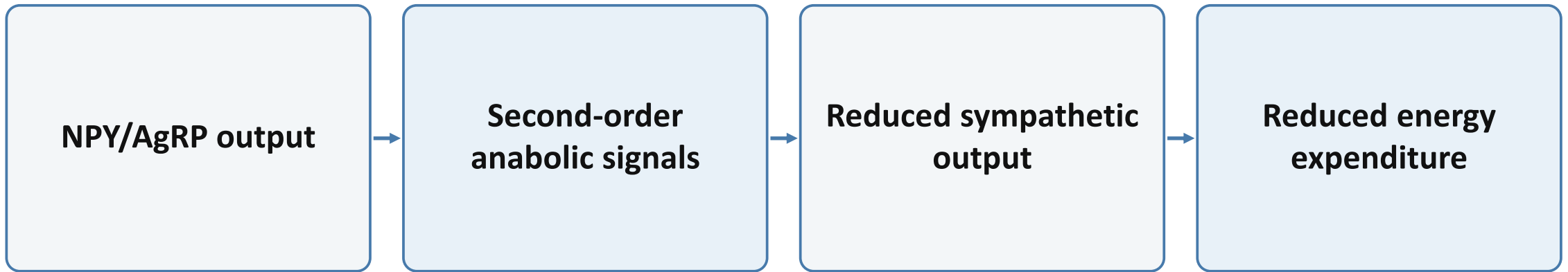
BDNF, TRH and CRH among mediators of second-order catabolic signalling.

NPY/AgRP neurons act as an appetite accelerator



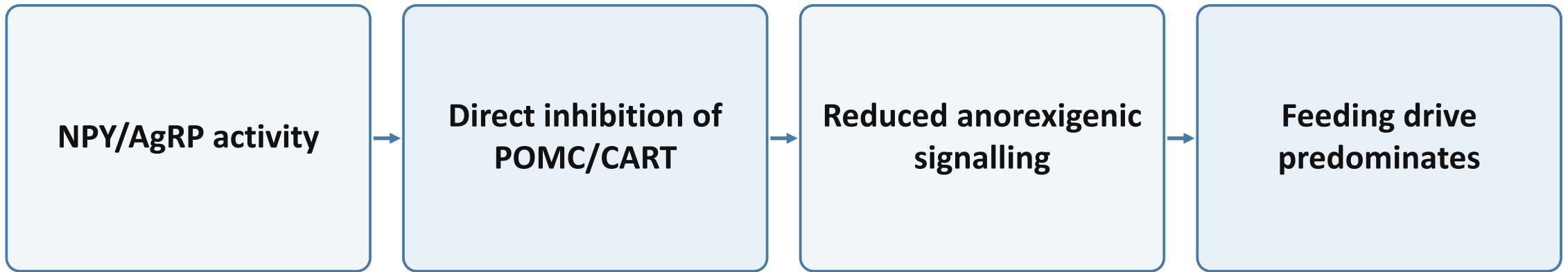
An orexigenic response conserves and replenishes energy stores.

Anabolic circuits also conserve energy



Downstream anabolic effects with MCH and orexin signalling.

NPY/AgRP inhibits the opposing neuronal arm

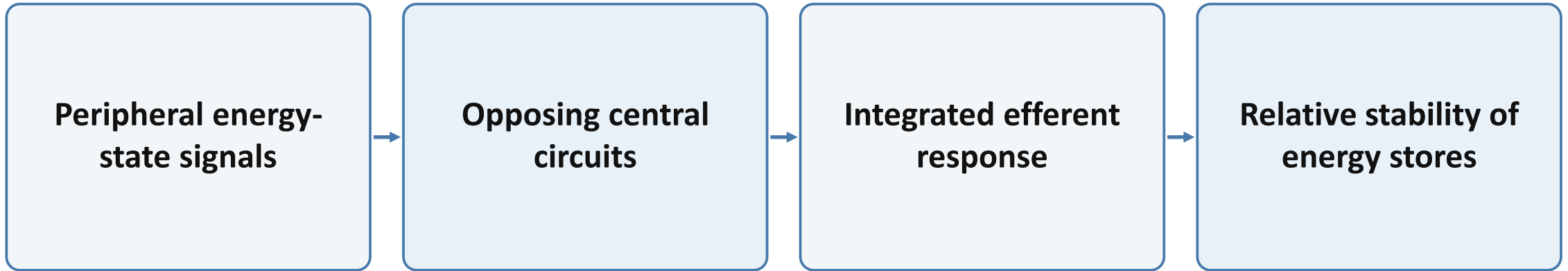


The reciprocal relationship strengthens the central response to fasting.

The two hypothalamic arms oppose one another

System	Catabolic arm	Anabolic arm
First-order neurons	POMC/CART	NPY/AgRP
Second-order signal	MC3/4 receptor pathway	Y1/Y5 receptor pathway
Effect on food intake	Decreases	Increases
Effect on energy expenditure	Increases	Decreases

Stable weight reflects balanced central signalling



The “lipostat” is a regulatory model for maintaining energy homeostasis, not a single anatomical structure.

Leptin modulates energy expenditure

Appetite

Suppresses intake through hypothalamic circuits.

Activity

Abundant leptin stimulates physical activity.

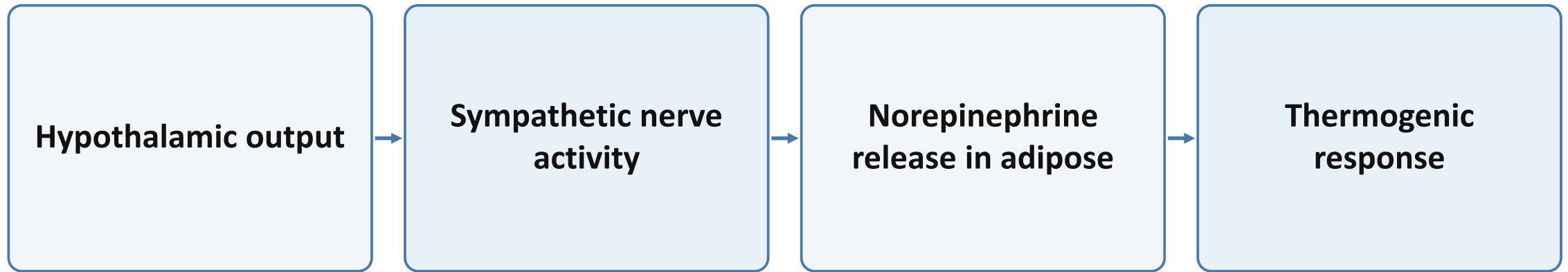
Heat

Supports thermogenesis and heat production.

Metabolic output

Promotes overall energy expenditure.

Sympathetic nerves connect brain and adipose tissue



This as a component of leptin-related heat production.

Leptin pathway genetics establish causal importance

Leptin loss of function

Insufficient adiposity signal despite energy stores.

Leptin receptor loss

Signal cannot be interpreted normally.

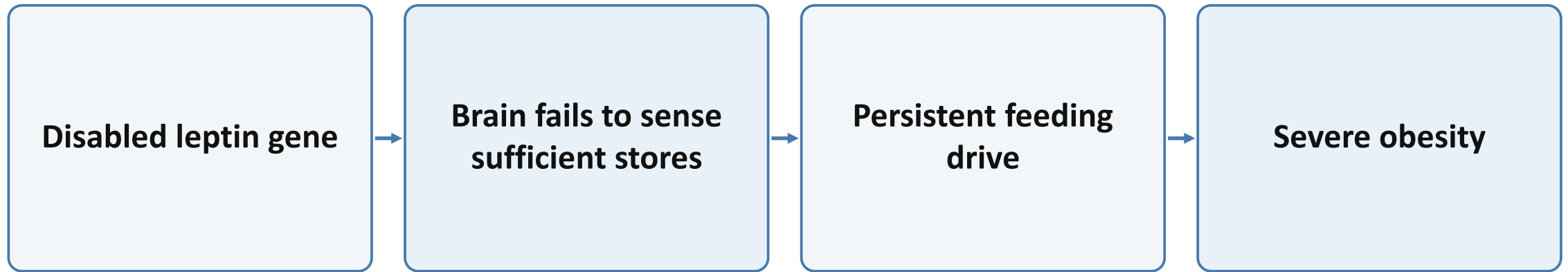
MC4R loss of function

Disrupts downstream melanocortin signalling.

Phenotype

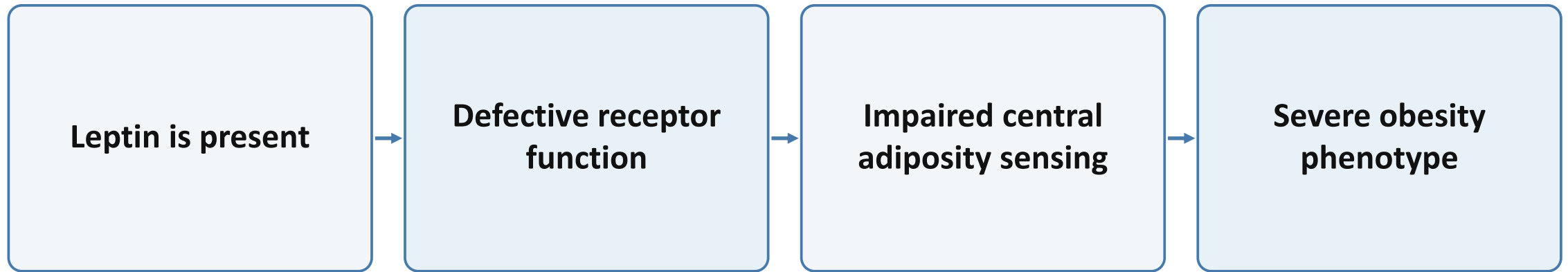
These monogenic abnormalities may cause severe obesity.

Leptin deficiency mimics a starvation signal



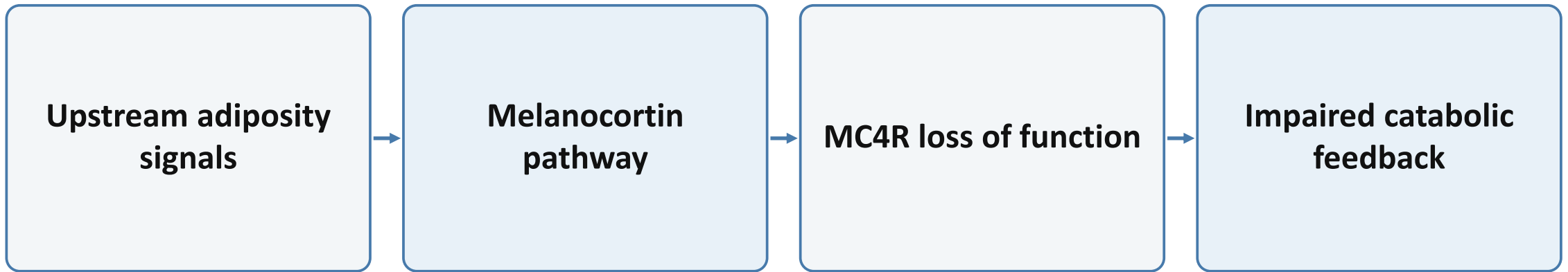
This principle using mouse models and rare human mutations.

Leptin-receptor defects disrupt feedback



Secretion of a hormone and biological response to that hormone are separate steps.

MC4R loss of function implicates downstream signalling

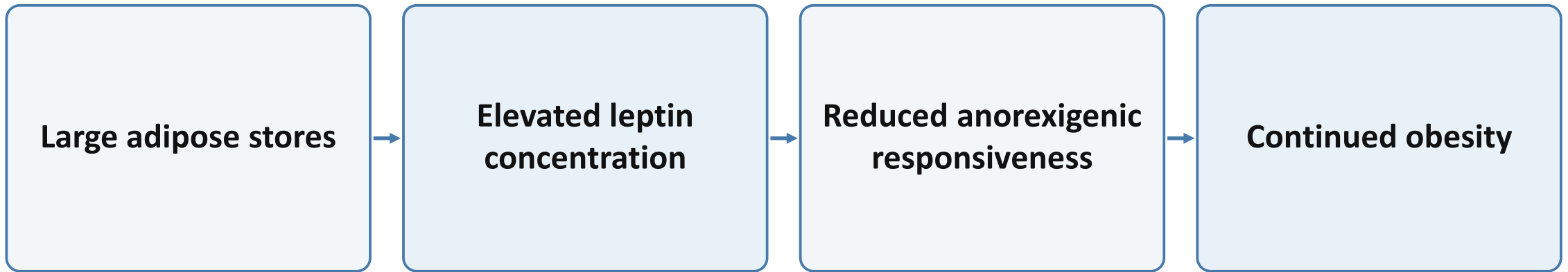


MC4R loss-of-function mutations in a subset of patients with massive obesity.

Leptin resistance differs from leptin deficiency

Feature	Leptin deficiency	Leptin resistance
Circulating leptin	Deficient	May be high in obesity
Biological problem	Insufficient hormonal signal	Blunted response to signal
Interpretation	Defective signal production	Impaired response despite signal

Why more leptin does not always suppress appetite



Leptin resistance as a limitation of leptin administration in common obesity.

Insulin contributes to central appetite regulation

Leptin

Secreted by fat cells.

Presented as the principal adiposity signal.

Insulin

Secreted by pancreas.

Receptors occur on POMC/CART and NPY/AgRP neurons; Also anorexigenic.

Adiponectin: A second major adipokine

Source

Produced in adipose tissue.

Fatty acids

Promotes oxidation in skeletal muscle.

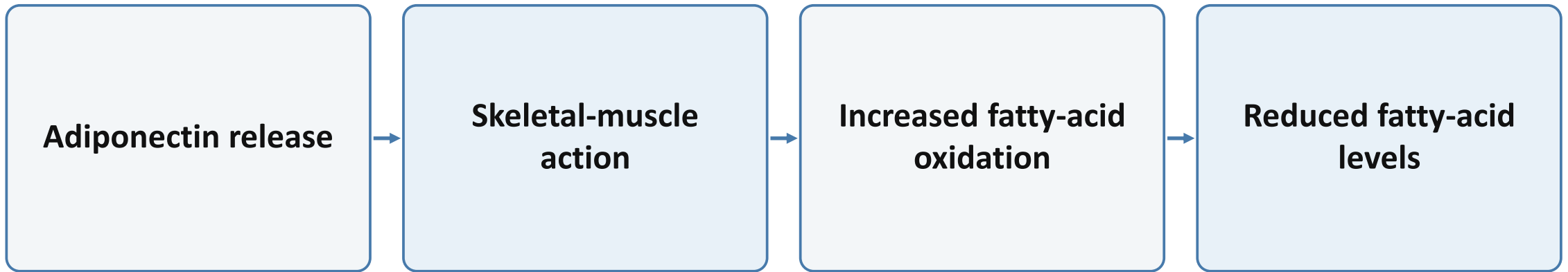
Glucose

Reduces hepatic glucose production.

Insulin action

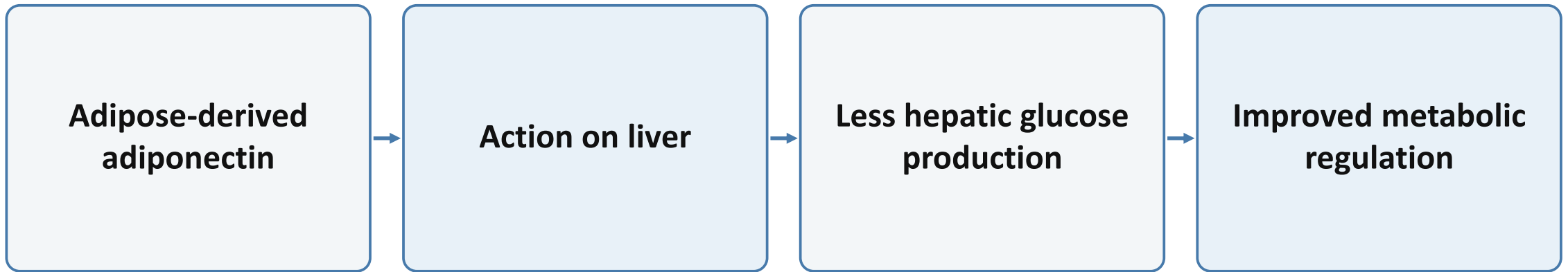
Increases insulin sensitivity.

Adiponectin enhances fatty-acid utilization



The pathway links adipose-derived signalling to peripheral fuel use.

Adiponectin reduces hepatic glucose output



This is one of the mechanisms associated with increased insulin sensitivity.

Adiponectin supports insulin sensitivity

Muscle

Stimulates fatty-acid oxidation.

Liver

Reduces glucose production.

Whole-body effect

Improves insulin responsiveness.

Clinical linkage

Supports protection against metabolic dysregulation.

Adiponectin concentrations vary with adiposity

Lean individuals

The text describes higher circulating adiponectin than in obesity.

Effects include improved fuel handling.

Individuals with obesity

Adiponectin levels tend to be lower.

Loss of its beneficial actions may accompany metabolic dysfunction.

Adiponectin effects extend beyond metabolism

Inflammation

Anti-inflammatory actions.

Blood vessels

Antiatherogenic actions.

Cell proliferation

Antiproliferative actions.

Heart

Cardioprotective actions.

Two adiponectin receptors distribute signaling

AdipoR1

Highly expressed in skeletal muscle.

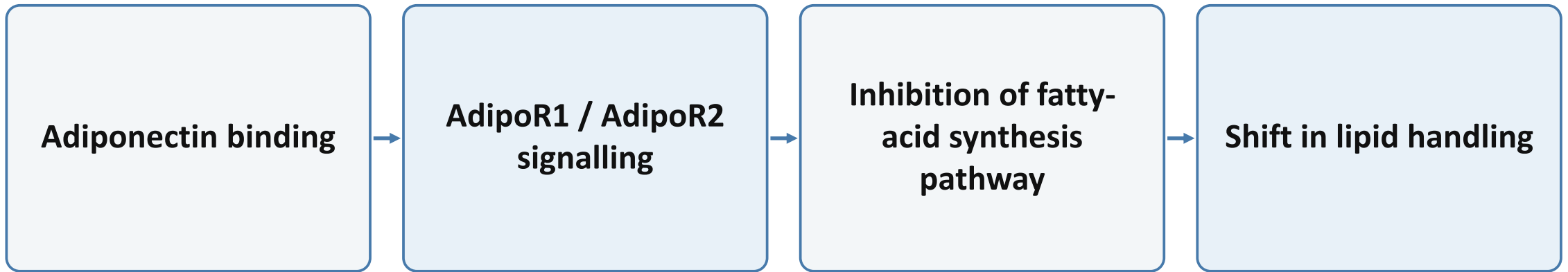
Receptor for adiponectin-mediated metabolic signalling.

AdipoR2

Highly expressed in liver.

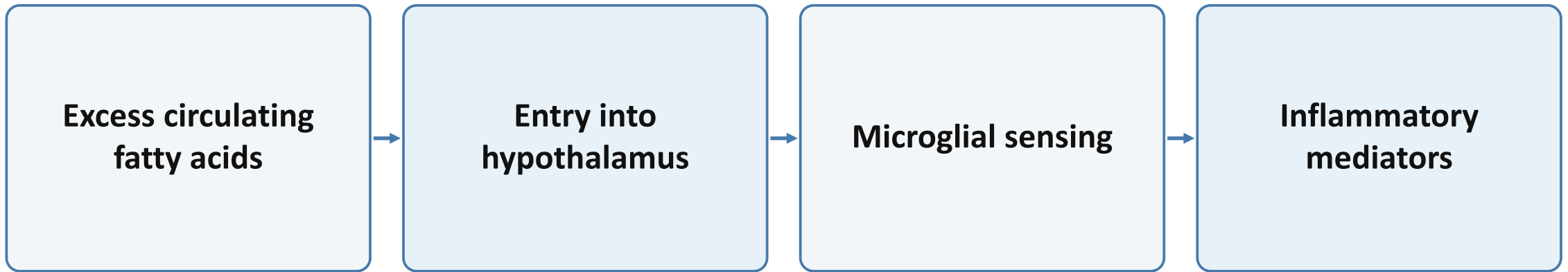
Receptor for adiponectin-mediated metabolic signalling.

Adiponectin links receptors to lipid metabolism



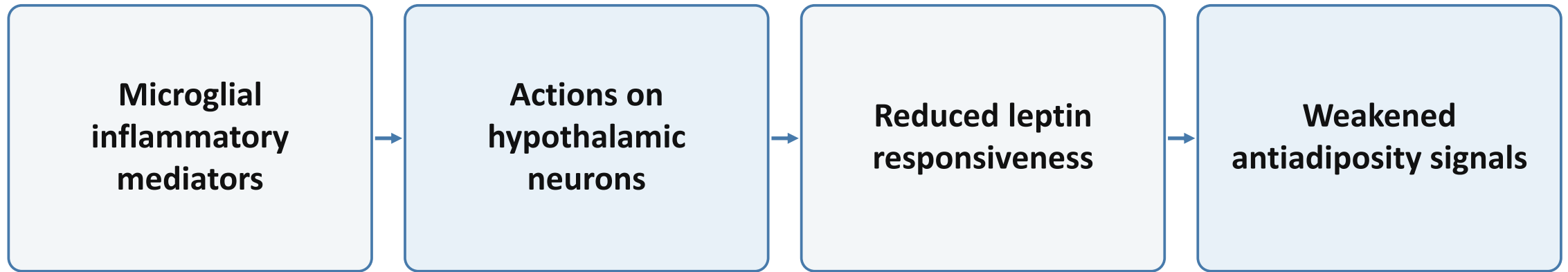
Acetyl-CoA carboxylase inactivation as a downstream consequence; Detailed kinase intermediates are omitted here.

Free fatty acids may influence hypothalamic signaling



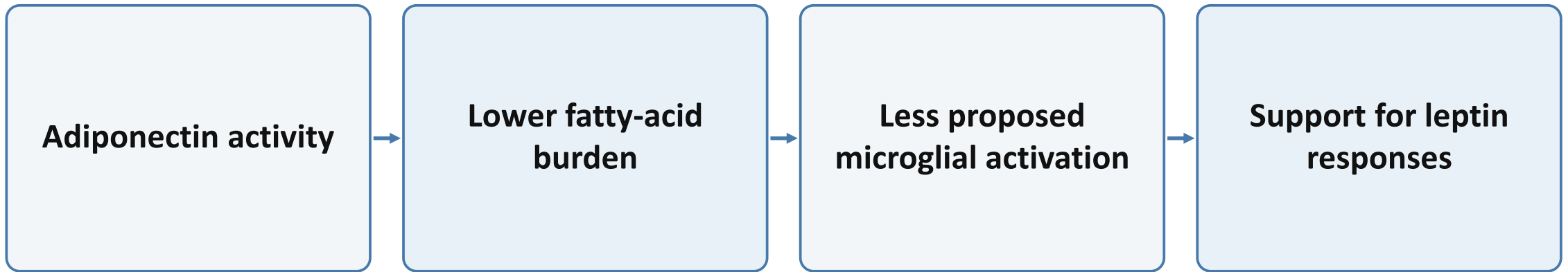
This is presented as evidence suggesting a contributory route, not as a complete established mechanism.

Hypothalamic inflammation may blunt leptin action



The proposed link is mechanistic and framed cautiously.

Adiponectin may counter a lipid–inflammation loop



Inferred integration of the textbook pathways; Not a clinical treatment claim.

White adipose tissue has a diverse secretome

Adipokines

Leptin and adiponectin.

Cytokines

TNF, IL-6, IL-1 and IL-18.

Chemokines

Inflammatory cell–recruiting signals.

Steroid hormones

Additional endocrine products.

Adipose-derived cytokines signal beyond fat

TNF

Listed as an adipose cytokine.

IL-6

Contributes to inflammatory signaling.

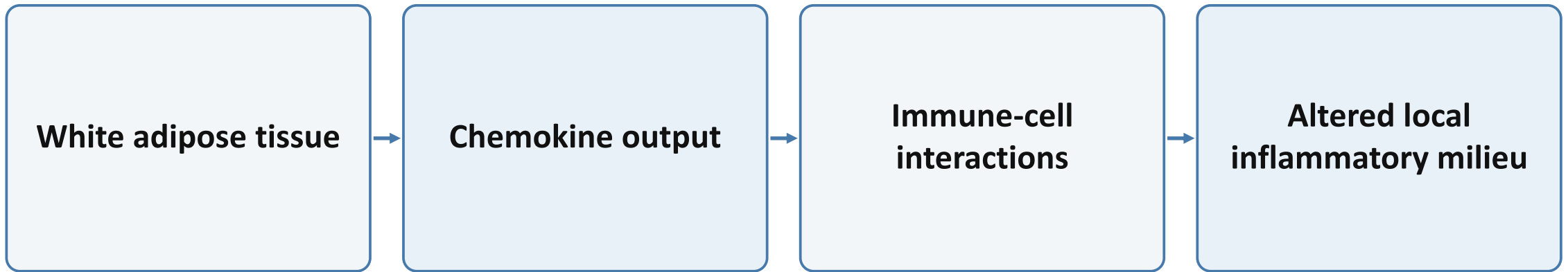
IL-1

Part of the adipose cytokine repertoire.

IL-18

Included in the adipose proinflammatory mediator profile.

Chemokines broaden adipose–immune communication



The source identifies chemokine production and immune reciprocity; This is a conceptual integration.

White adipose also produces steroid hormones

Endocrine identity

White fat synthesizes and releases steroid hormones in addition to adipokines.

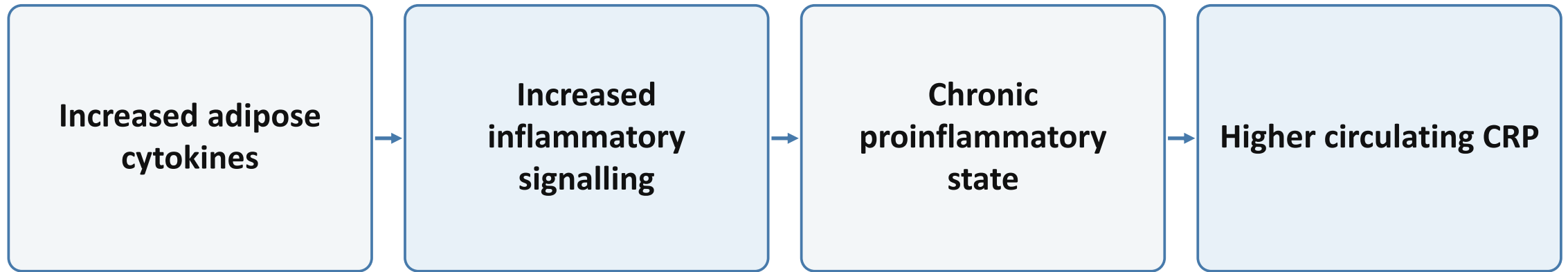
Its biology is therefore not restricted to energy storage.

Systems implication

Adipose influences metabolism and systemic signaling.

Specific steroid pathways are outside this subsection.

Obesity-associated adipose inflammation is systemic

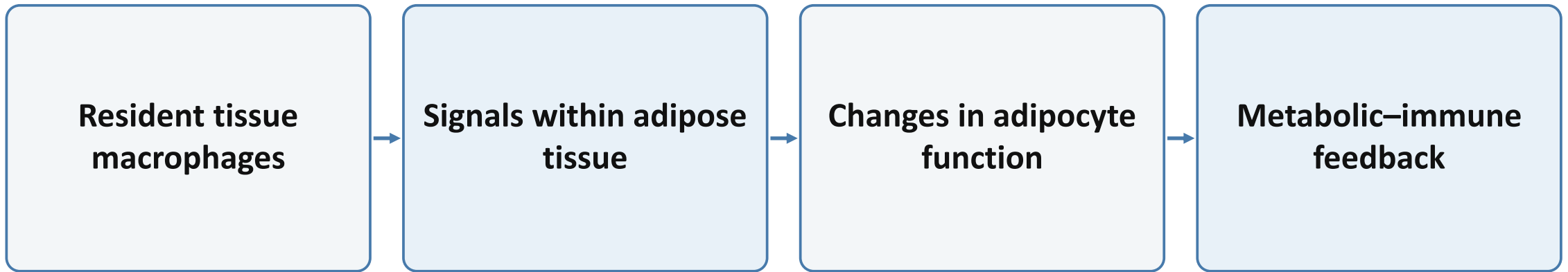


CRP is as a marker of the chronic proinflammatory state in obesity.

CRP is a systemic marker, not an adipokine

Component	Source / class	Teaching interpretation
TNF, IL-6, IL-1, IL-18	Adipose-associated cytokines	Upstream inflammatory mediators
Chemokines	White-adipose mediators	Recruitment / immune communication
C-reactive protein	Circulating inflammatory marker	Evidence of systemic inflammatory state

Macrophages participate in adipose regulation



The text identifies macrophage function as an emerging, reciprocal influence.

T cells contribute to adipose–immune crosstalk

Adipose → immune cells

Cytokines and chemokines affect immune pathways.

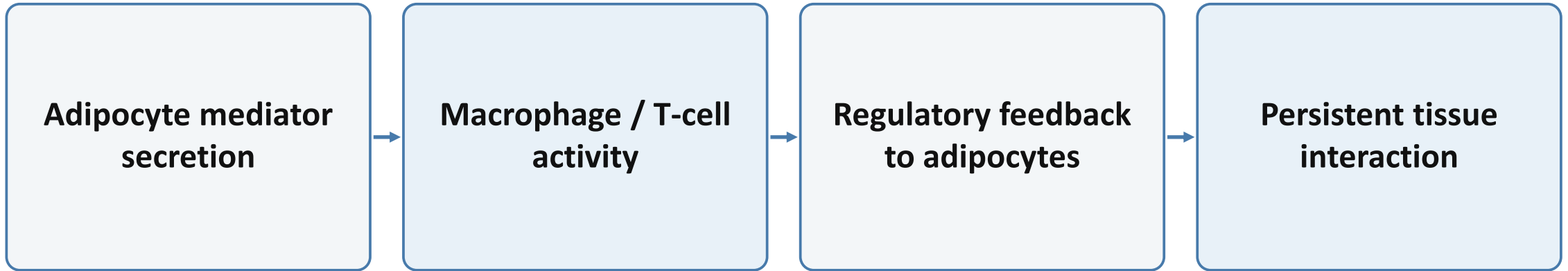
The tissue promotes a proinflammatory milieu in obesity.

Immune cells → adipose

Some T cells influence adipocyte function.

Evidence for reciprocal regulation.

Inflammation is not a one-directional pathway



An original conceptual schema of the bidirectional signaling.

White adipose integrates three systems

Lipid metabolism

Storage and use of energy substrates.

Nutrition

Signals about sufficiency of energy stores.

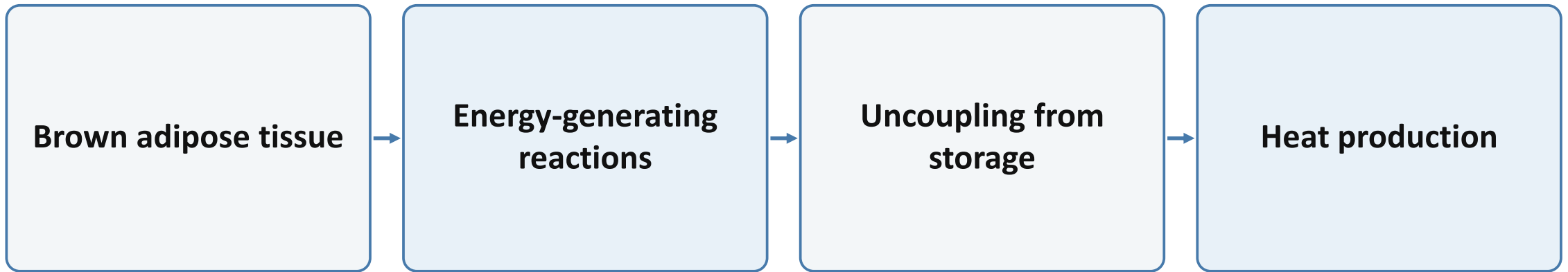
Inflammation

Cytokines, chemokines and immune-cell regulation.

Systemic physiology

Endocrine effects on multiple organs.

Brown adipose tissue generates heat



The defining function is nonshivering thermogenesis.

Thermogenesis is distinct from energy storage

Physiological route	Energy fate	Dominant tissue context
Energy conservation	Stored for later use	White adipose tissue
Nonshivering thermogenesis	Released as heat	Brown adipose tissue
Whole-body relevance	Energy balance	Intake–expenditure regulation

Brown adipose is prominent in newborns

Newborn pattern

Brown adipose tissue is abundant early in life.

Prominent deposits occur in interscapular and supraclavicular regions.

Physiological meaning

Nonshivering thermogenesis permits energy expenditure as heat.

No shivering is needed for this mechanism.

Brown adipose has several described locations

Principal regions

Interscapular and supraclavicular.

Perivisceral regions

Around kidneys and aorta.

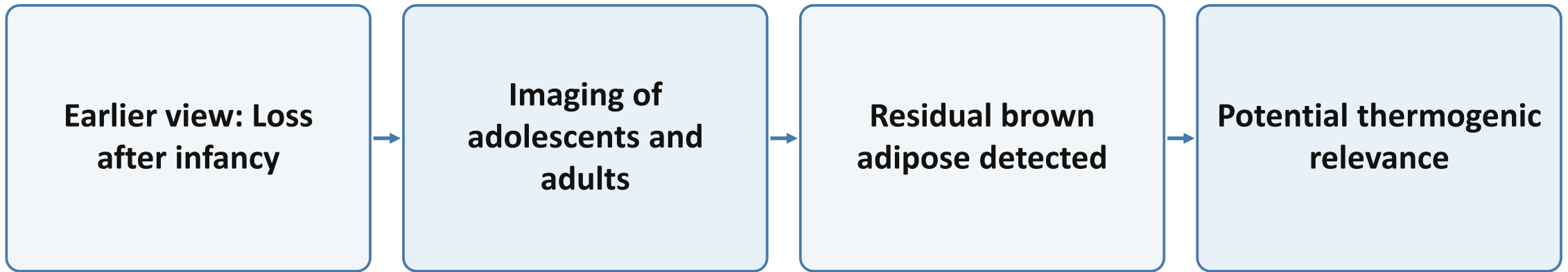
Thoracic / cardiac regions

Around heart and trachea.

Other reported site

Around pancreas.

Brown adipose tissue can persist into adulthood



The original text reports persistence demonstrated by imaging rather than quantitative prevalence.

Thermogenic activation is under investigation

Preservation

How can brown adipose tissue be retained or maintained in adulthood?

This is a research direction, not an established intervention in this subsection.

Activation

Can preserved brown adipose increase expenditure of energy as heat?

The textbook frames activation as an area of active investigation.

White and brown adipose have complementary roles

Dimension	White adipose	Brown adipose
Physiological priority	Stores fuel; senses fuel stores	Dissipates energy as heat
System communication	Hormones and inflammatory mediators	Neural thermogenic responsiveness
Clinical insight	Adiposity and inflammation	Potential energy-expenditure lever

Case: High leptin does not imply intact satiety

An adult with obesity has abundant fat stores but does not show an appropriately strong anorexigenic response to adiposity signals.

What mechanism reconciles large fat stores with continuing feeding drive?

Interpretation: Leptin resistance — response is blunted despite high leptin in obesity.

Case: Fat distribution alters risk interpretation

Two adults have similar overall excess body weight. One has predominantly visceral fat; The other mainly subcutaneous accumulation.

Why can their disease risk differ despite comparable overall adiposity?

Interpretation: Central/visceral distribution carries a stronger association with several obesity-related disorders.

Adipose endocrine and immune pathways converge

Signal of energy stores

Leptin communicates adiposity to the hypothalamus.

Metabolic protection

Adiponectin supports lipid oxidation and insulin sensitivity.

Inflammatory signals

White adipose cytokines and chemokines link to CRP.

Energy dissipation

Brown adipose performs nonshivering thermogenesis.

Core principles for pathology teaching

- Adipose tissue influences both energy balance and systemic inflammatory biology.
- White adipose tissue releases leptin, adiponectin, cytokines, chemokines and steroid hormones.
- Brown adipose tissue uses nonshivering thermogenesis; Some persists in adults.
- Feedback failure, altered adipokines and immune-cell interactions help explain metabolic effects of obesity.

Primary source and scope

Robbins, Cotran & Kumar: Pathologic Basis of Disease. 11th ed. (2026). Chapter 9: Environmental and Nutritional Diseases.

“Adipose Tissue,” p. 407, with surrounding “Obesity,” “Leptin” and “Adiponectin” material, pp. 404–407.

The primary source discussion spans the sections “Obesity,” “Leptin,” “Adiponectin” and “Adipose Tissue.”

For the central energy-balance circuitry, see the textbook’s Figure 9.28.