

Figure legends

Fig.1. A biological algorithm describing a simplified model of the immune response.

Viruses, bacteria, fungi and parasites which have penetrated vertebrate organisms can be recognized and destroyed by the immune system. The response to these foreign substances or antigens is mainly ensured by B and T lymphocytes and white blood cells. The alert is given by the B cells and the macrophages which capture the antigen and present it to Th (T helper) cells which secrete cytokines to amplify the signal and this continues as long as the antigen is present .

step 1: The B cells recognize the antigen with a surface immunoglobulin which ensures specific recognition. Macrophages capture the foreign body present in the organism in a non-specific manner by an endocytosis reaction which degrades the foreign substance. Both types of cells present fragments of the antigen in association with MHC class II molecules. B cells also synthesize receptors for cytokines.

Meanwhile, the organism's target cells are being attacked, generally via their receptors, notably in the case of viruses. These infected cells present elements of antigens neosynthesized for the benefit of the invader, either in association with a MHC class I molecule or on the cell surface.

step 2: Th (T helper) cells are equipped with a receptor which is specific for the antigen and which recognizes the antigen fragments present in association with MHC class II molecules presented by cells and macrophages. The Th cells then secrete cytokines.

First elimination of infected cells: the Tc cells (cytotoxic T cells) recognize antigen fragments presented in association with MHC class I molecules of infected cells, and destroy the cells.

step 3: The B cells receive the message from the cytokines: they must divide and secrete antibodies. This is a confirmation of specific recognition before engagement in clonal selection.

The Th and Tc cells also receive the cytokine message and divide.

step 4: Circulating antibodies bind with circulating antigens to facilitate recognition by macrophages and phagocytes. Antibodies also bind to antigens present on the surface of infected cells to facilitate recognition by NK (natural killer) cells.

Fig.2. A biological algorithm describing a simplified model of glycogen metabolism.

The presence of glucose in the organism triggers the insulin signal which activates the formation of glycogen (glycogenesis) controlled by glycogen-synthase and inhibits its degradation (glycogenolysis) catalysed by glycogen-phosphorylase. Similarly, insulin favors glycolysis, which is the utilization of glucose by the tissues and inhibits gluconeogenesis. Conversely, a need for glucose triggers the glucagon signal which activates the degradation of glycogen (glycogenolysis) and resynthesis of glucose from pyruvate (gluconeogenesis) and inactivates the two competing pathways.

The substrates transformed by the metabolic pathways are not modeled and are assumed to be present in sufficient quantities. Only the mechanisms of regulation are represented: the hormone signal, transduction and activation of key enzymes of the metabolic pathways. The action of the key enzymes for a metabolic pathway is not detailed : the progression of enzymes that serve as catalysts for a metabolic pathway form a code which switches on or off; these enzymes form the code for the metabolic pathway or word of the language.

In both of these cases (insulin/glucagon), transduction of the signal leads to two results: activation of the proper metabolic pathway and inactivation of the opposite one. Only one transduction can be presented in detail as a succession of binding events, the one that activates glycogenolysis and inactivates glycogenesis under the control of glucagon; other transductions are not sufficiently well-understood at the level of each intermediate reaction—they are represented by a single transition (transduction).

Fig. 1.

1st operand			2nd operand			operator		Result			
cell1	molecule1	type1	cell2	molecule2	type2	action	cellRes	moleculeRes	typeRes	state	
targetCell	cellReceptor	receptor	-	antigen	circulating	EXPRESSION	targetCell	MHC_II+antigen	receptor	activated	
targetCell	cellReceptor	receptor	-	antigen	circulating	EXPRESSION	targetCell	antigen	receptor	activated	
Bcell	antibody_ig	receptor	-	antigen	circulating	EXPRESSION	Bcell	MHC_II+antigen	receptor	activated	
Bcell	antibody_ig	receptor	-	antigen	circulating	EXPRESSION	Bcell	cytokinReceptor	receptor	activated	
ThCell	Treceptor	receptor	Bcell	MHC_II+antigen	receptor	EXPRESSION	-	cytokine	circulating	activated	
ThCell	Treceptor	receptor	Bcell	MHC_II+antigen	receptor	EXPRESSION	ThCell	cytokinReceptor	receptor	activated	
Bcell	cytokinReceptor	receptor	-	cytokine	circulating	EXPRESSION	-	antibody	circulating	activated	
-	antigen	circulating	-	antibody	circulating	EXPRESSION	-	antigen+antibody	circulating	activated	
targetCell	antigen	receptor	-	antibody	circulating	EXPRESSION	targetCell	antigen+antibody	receptor	activated	
macrophage	Mreceptor	receptor	-	antibody	circulating	EXPRESSION	macrophage	antigen+antibody	receptor	activated	
macrophage	FcReceptor	receptor	-	antigen	circulating	EXPRESSION	-	MHC_II+antigen	-	-	
ThCell	Treceptor	receptor	-	antigen+antibody	circulating	DESTRUCTION	-	antigen+antibody	-	-	
Bcell	Treceptor	receptor	macrophage	MHC_II+antigen	receptor	EXPRESSION	-	cytokine	circulating	activated	
Bcell	cytokinReceptor	receptor	-	cytokine	circulating	CELLDIVISION	Bcell	-	-	-	
ThCell	cytokinReceptor	receptor	-	cytokine	circulating	CELLDIVISION	ThCell	-	-	-	
TcCell	cytokinReceptor	receptor	-	cytokine	circulating	CELLDIVISION	TcCell	-	-	-	
TcCell	Treceptor	receptor	targetCell	MHC_II+antigen	receptor	CELLEDIVISION	targetCell	-	-	-	
Kcell	FcReceptor	receptor	targetCell	antigen+antibody	receptor	CELLEDIVISION	targetCell	-	-	-	

Fig. 2.

1st operand			2nd operand			operator			Result		
cell1	molecule1	type1	cell2	molecule2	type2	action	cellRe_s	moleculeRes	typeRes	state	
liver	insulin receptor	receptor	-	insulin	circulating	TRANSDUCTION	liver	glycogen-synthase	cytoplasmic	activated	
liver	glycogen-synthase	cytoplasmic	liver	-	-	METABOLIC PATHWAY	liver	glycogen	cytoplasmic	-	
liver	insulin receptor	receptor	-	insulin	circulating	TRANSDUCTION	liver	glycolysis key enzymes	cytoplasmic	activated	
liver	glycolysis key enzymes	cytoplasmic	liver	-	-	METABOLIC PATHWAY	liver	pyruvate	cytoplasmic	-	
liver	insulin receptor	receptor	-	insulin	circulating	TRANSDUCTION	liver	gluconeogenesis key enzymes	cytoplasmic	inactivated	
liver	insulin receptor	receptor	-	insulin	circulating	TRANSDUCTION	liver	glycogen-phosphorylase	cytoplasmic	inactivated	
liver	glucagon receptor Ext	receptor	-	glucagon	circulating	TRANSDUCTION	liver	gluconeogenesis key enzymes	cytoplasmic	activated	
liver	gluconeogenesis key enzymes	cytoplasmic	liver	-	-	METABOLIC PATHWAY	-	glucose	circulating	-	
liver	glucagon receptor Ext	receptor	-	glucagon	circulating	TRANSDUCTION	liver	glycolysis key enzymes	cytoplasmic	inactivated	
-	glucagon	circulating	liver	glucagon receptor Ext	receptor	BINDING	liver	glucagon receptor Int	receptor	activated	
liver	glucagon receptor Int	receptor	liver	G-protein	cytoplasmic	BINDING	liver	G-protein	cytoplasmic	activated	
liver	G-protein	cytoplasmic	liver	adenylate-cyclase	cytoplasmic	BINDING	liver	adenylate-cyclase	cytoplasmic	activated	
liver	adenylate-cyclase	cytoplasmic	liver	ATP	cytoplasmic	BINDING	liver	cAMP	cytoplasmic	activated	
liver	AMPc	cytoplasmic	liver	protein kinase A	cytoplasmic	BINDING	liver	protein kinase A	cytoplasmic	activated	
liver	protein kinase A	cytoplasmic	liver	phosphorylase-kinase	cytoplasmic	BINDING	liver	phosphorylase-kinase	cytoplasmic	activated	
liver	phosphorylase-kinase	cytoplasmic	liver	glycogen-phosphorylase	cytoplasmic	BINDING	liver	glycogen-phosphorylase	cytoplasmic	activated	
liver	phosphorylase-kinase	cytoplasmic	liver	glycogen-synthase	cytoplasmic	BINDING	liver	glycogen-synthase	cytoplasmic	inactivated	
liver	glycogen-phosphorylase	cytoplasmic	liver	-	-	METABOLIC PATHWAY	-	glucose	circulating	-	