Physics of antigen recognition and of its interaction with electromagnetic waves.

Antigen recognition and its interaction with electromagnetic waves is based on transitions between a total of at least 4 wells. It does not depend on the electromagnetic wave being pulsed or amplitude modulated and when the electromagnetic wave is typically gaussian, it does not exhibit power windows (but it may exhibit them in specific cases if the electromagnetic wave is pulsed or amplitude modulated).

The physics of antigen recognition and of its interaction with electromagnetic waves is described in (Lauer 2014). The present document gives a brief outline of it.

The interaction of antigen recognition with electromagnetic is an indirect consequence of the natural mechanism of antigen recognition, which will be described first.

1. Antigen recognition

The basic unit involved in antigen recognition comprises the T Cell Receptor, antigen(p) and Major Histocompatibility Complex (TCR-pMHC)) and can be represented in a multidimensional space representing coordinates of the atoms of the TCR-pMHC. Figure B1 shows only two coordinates *x, y* as it is not possible to represent the full multi-dimensional reality, and a conformational energy E depends on *x* and *y*, thus defining a surface. As an analogy, the TCR-pMHC behaves like a ball on this (virtual) surface, so that it tends to stabilize in valleys or wells corresponding to distinct conformations (i.e. distinct spatial arrangements, without changes in chemical bounds). Well (a) is the initial conformation, wells (c) and (d) respectively trigger states CR and ANR of the lymphocyte (if inhibitory receptors are present, a sufficient number of TCR-pMHCs entering well (c) may be necessary to trigger state CR), and well (b) is an intermediate conformation.

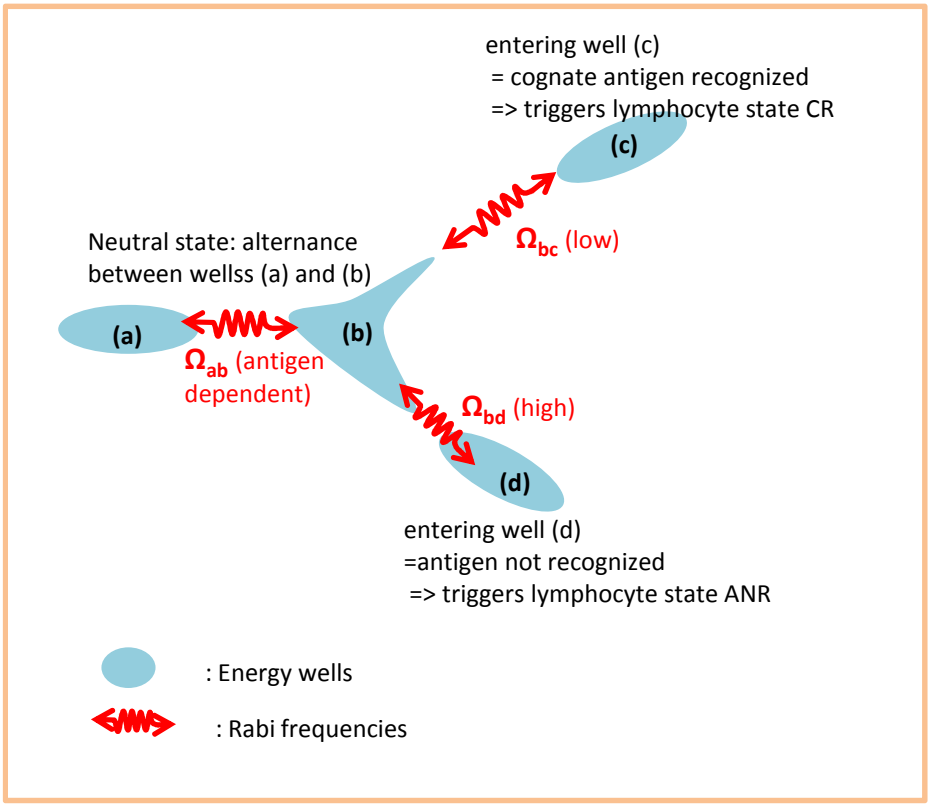

Figure B1: 2-dimensional view of quantum states (a), (b), (c), (d). This is a projection in the *x,y* plane of the energy surface.

Figure B2 shows energy as a function of the coordinate *s* along the minimum energy path linking wells (a) (b) and (c). In quantum mechanics, the energy of the TCR-pMHC in each well can take discrete values represented as horizontal lines of figure B2, corresponding to vibrational energy levels. The TCR-pMHC having such quantized energy is said to be in a corresponding "quantum state".

antigen recognition

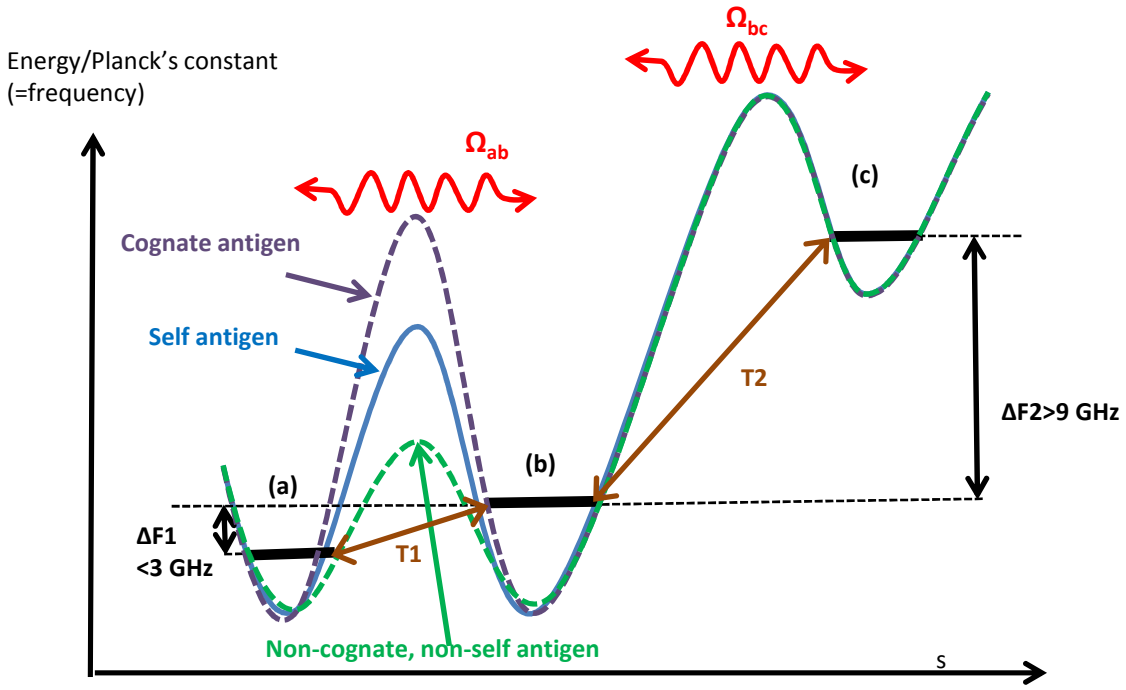

Figure B2: energy profile along minimum energy path showing quantum wells (a), (b) and (c). Quantum states in each well are shown as horizontal bars. Rabi frequency $\Omega_{ab,}$ [resp. Ω_{bc}] is the frequency of quantum oscillations of the system between quantum wells (a) and (b) [resp. (b) and (c)] . Frequency difference **ΔF1** [resp. **ΔF2**] is the frequency of the electromagnetic wave adapted to cause transition **T1** [resp. **T2**] between the quantum states shown as horizontal bars in wells (a) and (b) [resp. (b) and (c)]. This is a section of Figure B1 along line (a) (b) (c). It is assumed that the T lymphocyte has survived positive and negative selection.

Transitions between wells are stimulated by the thermal background electromagnetic field ("thermal noise"). The direct transition between two wells (more appropriately: between quantum states in each of the two wells) has a Rabi frequency (i.e. frequency of oscillations of the TCR-pMHC between the wells, comparable to the oscillation frequency of a violin's string). Quantum mechanics shows that when the Rabi frequency Ω_{ab} of the (a) to (b) transition equals the Rabi frequency Ω_{bc} of the (b) to (c) transition ($\Omega_{ab} = \Omega_{bc}$) a "coupling mechanism" maximizes the overall transition probability from (a) to (c) (as an analogy, the oscillations of a string are better transmitted to another string having the same oscillation frequency). Likewise, the overall transition probability from (a) to (d) is maximized if the Rabi frequency of the (a) to (b) transition equals the Rabi frequency of the (b) to (d) transition.

Quantum mechanics basics

The following equation describes how the amplitude of the wavefunction evolves when there is only a single quantum state in each well:

$$|\phi(t)\rangle = \left[\frac{\Omega_{bc}^2}{\Omega_{ab}^2+\Omega_{bc}^2} + \frac{\Omega_{ab}^2}{\Omega_{ab}^2+\Omega_{bc}^2}\cos\left(\frac{t}{2}\sqrt{\Omega_{ab}^2+\Omega_{bc}^2}\right)\right]|a\rangle + i\frac{\Omega_{ab}}{\sqrt{\Omega_{ab}^2+\Omega_{bc}^2}}\sin\left(\frac{t}{2}\sqrt{\Omega_{ab}^2+\Omega_{bc}^2}\right)|b\rangle - \frac{\Omega_{bc}\Omega_{ab}}{\Omega_{ab}^2+\Omega_{bc}^2}\left[1-\cos\left(\frac{t}{2}\sqrt{\Omega_{ab}^2+\Omega_{bc}^2}\right)\right]|c\rangle$$

(Equation 1)

The probability of the (a) to (c) transition is maximal if $\Omega_{bc} = \Omega_{ab}$. When $\Omega_{bc} << \Omega_{ab}$ the probability of the (a) to (c) transition increases when Ω_{ab} diminishes.

antigen recognition

The height of the barrier between wells (a) and (b) and therefore the Rabi frequency Ω_{ab} of the (a) to (b) transition depends on the antigen. The Rabi frequency Ω_{ab} is intermediate between a lower Rabi frequency Ω_{bc} of the (b) to (c) transition and a higher Rabi frequency Ω_{bd} of the (b) to (d) transition ($\Omega_{bc} < \Omega_{ab} < \Omega_{bd}$). Positive [resp.negative] thymus selection eliminates lymphocytes that make transitions to well (d) [resp.(c)] in the presence of self antigens so that the TCR-pMHC complexes of lymphocytes having survived thymus selection normally make a transition to well (d) or (c) only upon an encounter with a non-self antigen. Where the non-self antigen blocks the path from (a) to (b) by increasing the energy barrier as shown on Figure B2, it opposes (a) to (b) oscillations yielding a low Ω_{ab} (near to Ω_{bc}) and causing a transition to well (c) triggering state CR. When the non-self antigen yields a high Ω_{ab} (near to Ω_{bd}) then it causes a transition to well (d) triggering state ANR.

Blocking of the (a) to (b) path by the antigen takes place in a multidimensional space. In a three-dimensional picture it can be represented as below on figure B3. The antigen blocks the (a) to (b) path like a plug having exacly the exact shape blocks a pipe having a corresponding cross section. If the "shape" of the antigen is not precisely correct, there remains a path of relatively low energy between (a) and (b). Thus, blocking of the (a) to (b) path is an extremely selective process, able to recognize only a specific antigen.

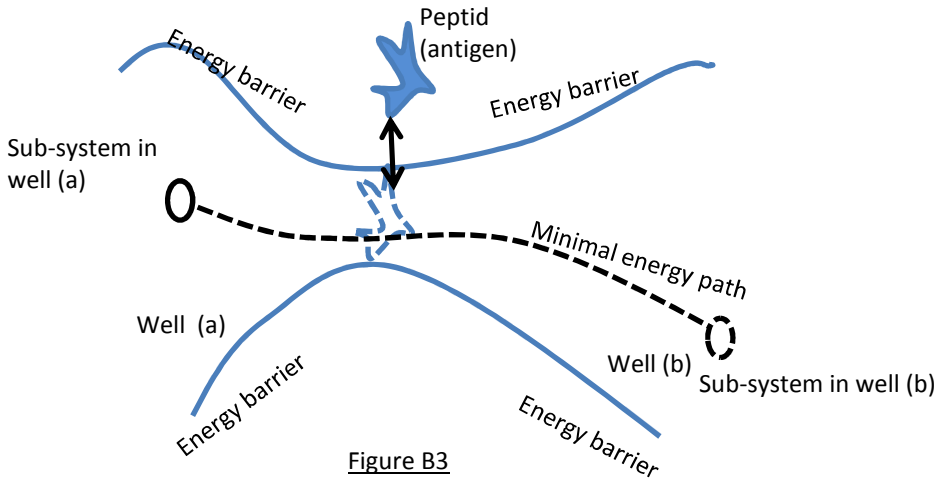

Figure B3

This mechanism of antigen recognition responds to the following needs:

a) Recognizing the cognate antigen. This requires a highly selective mechanism and is realized by having the antigen block the (a) to (b) path.

b) Triggering state CR when the cognate antigen is recognized: this is realized by the arrangement of well (c) and the Ω_{bc} Rabi frequency, which are adapted to trigger entry into well (c) when the antigen blocks the (a) to (b) path, with entry into well (c) triggering state CR of the lymphocyte.

c) Triggering state ANR when the antigen is not recognized as cognate nor as self antigen. This is realized by well (d) and the Rabi frequency Ω_{bd} , which are adapted to trigger entry into well (d) when the antigen is non-self non-cognate, with state (d) triggering state ANR of the lymphocyte.

2. Interaction of antigen recognition with electromagnetic waves.

Stimulation of (a) to (b) transitions by an artificial electromagnetic wave in addition to the thermal electromagnetic field increases the Rabi frequency Ω_{ab} which is proportional to field strength.

Quantum states in wells (a) and (b) have comparable energies, and transitions between these states can be stimulated by electromagnetic waves having frequencies of less than 3 GHz (figure B2) resulting in an increased value of Ω_{ab},

bringing Ω_{ab} farther from Ω_{bc} and thus inhibiting (a) to (c) [i.e. state CR] transfers **(mechanism INH),** and bringing Ω_{ab} nearer to Ω_{bd} and favoring (a) to (d) [i.e. state ANR] transfers **(mechanism INA).**

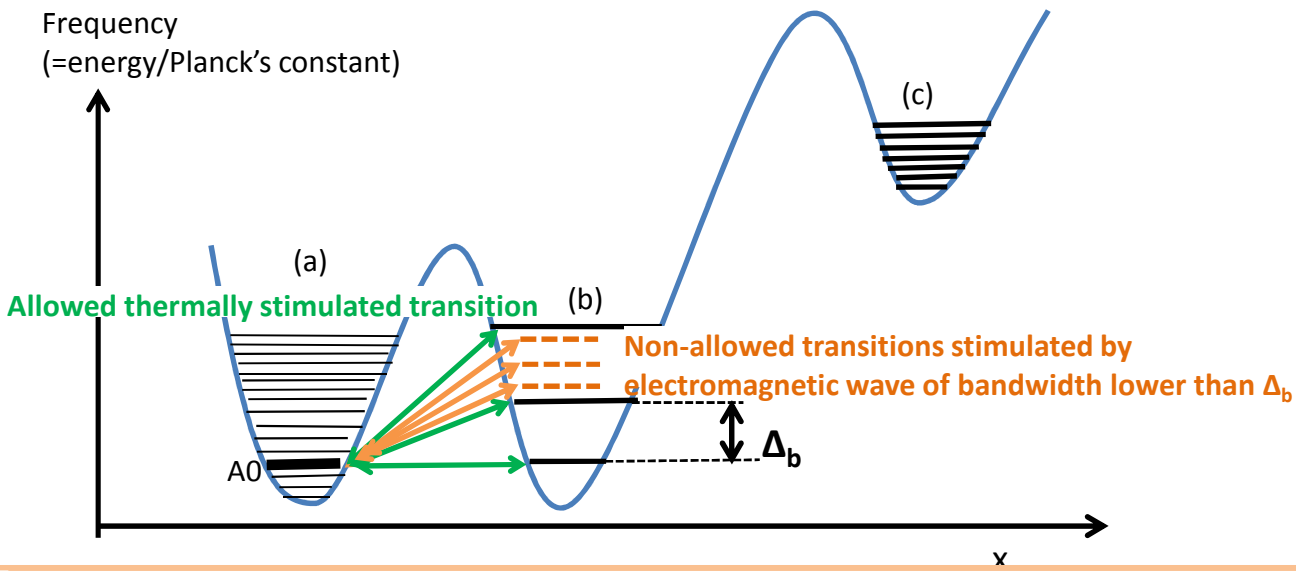

Figure B4: Transitions from quantum state A0 to quantum states in well (b) cannot be stimulated due to insufficient bandwidth; Transitions from quantum state A0 to well (c) are therefore not inhibited. Inhibition of transitions from (a) to (c) is incomplete and strongly limited.

Mechanism INH requires a sufficient bandwidth (figure B4). But mechanism INA can operates with very low bandwidth, because when transitions from state A0 to well (d) cannot be directly stimulated, a system in state A0 can still make an indirect transition to well (d) through intermediate states in well (a). The difference between the situation is comparable to the following image: If five pathes go from (a) to (c) it is necessary to block each of them in order to block access to (c). But if no path goes from (a) to (d) it is only necessary to open one path so as to reach (d).

In (very) short: transitions from (a) to (b) are powered by the thermal electromagnetic backround (thermal noise) below 3 GHz,.
When an artificial electromagnetic wave is added to the thermal background, it affects (a) to (b) transitions and thus antigen recognition.
Since the thermal background below 3 GHz has a very low power, antigen recognition can potentially be affected by artificial waves having comparably low power.

This fact that low power waves disturb antigen recognition is mitigated by a number of facts: for example a line of T lymphocytes which becomes unable to recognize an antigen can be replaced by another line of T lymphocytes,

Interaction of antigen recognition with electromagnetic waves.

Power windows in the interaction of antigen recognition with electromagnetic waves.

Based on equation 1, if the wave is pulsed the system's probability of being in state (c) at the end of the interaction (square of the coefficient of |c> in the equation) varies sinusoidally with the Rabi frequency Ω_{ab} which is proportional to power. This potentially determines power windows where the wave is pulsed or generally has repetitive features. Such power windows are observable for example in (Jacob's univ. 2008).

Direct stimulation of the (b) to (c) transition above 9 GHz.

Until now we have discussed only stimulation of the (a) to (b) transition by electromagnetic waves below 3 GHz.

Above 9 GHz, the (b) to (c) transition is stimulated instead of the (a) to (b) transition, resulting in an increased value of Ω_{bc} , thus bringing Ω_{bc} nearer to Ω_{ab} and favoring (a) to (c) [i.e. state CR] transfers **(mechanism M3).** This mechanism is observable for example in Fesenko & al.

Between 3 and 9 GHz there are no experimental results available so that this is an uncertainty area.

3. Conclusion

The mechanism of antigen recognition is based on thermally stimulated transitions and responds to the need of realizing the basic functions of transitions to state CR upon recognition of the cognate antigen and to state ANR upon recognition of the non-cognate non-self antigen.

The interaction of electomagnetic waves with T lymphocytes is a consequence of the natural mechanism of thermally stimulated antigen recognition.

References:

Jacobs University Bremen. Abschlussbericht fur das Forschungsvorhaben: Langzeitstudie an Labornagern mit UMTS-Signalen. January 2008.

Lauer V.. A model of the interaction of T lymphocytes with electromagnetic waves. HAL : hal-00975963, version Hyper Articles en Ligne. 2014. http://hal.archives-ouvertes.fr/hal-00975963.