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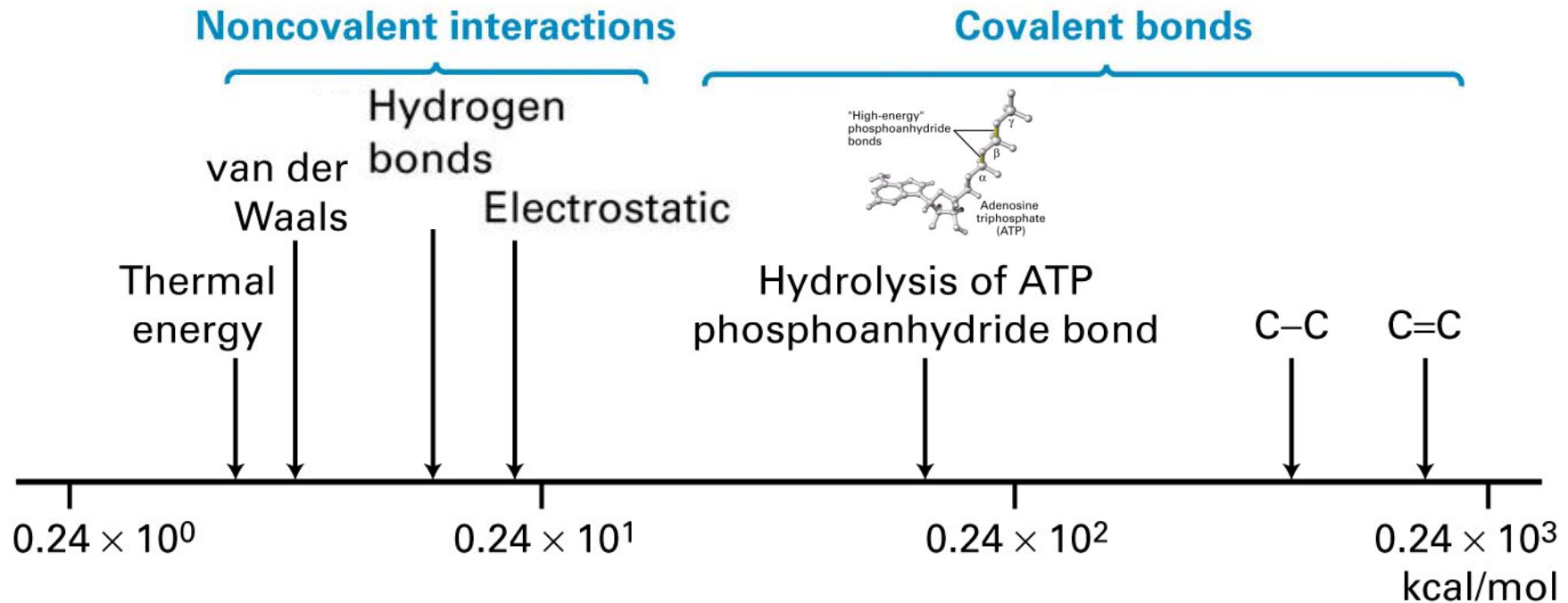
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# Lecture

## *Noncovalent Interactions*

# Noncovalent Interactions



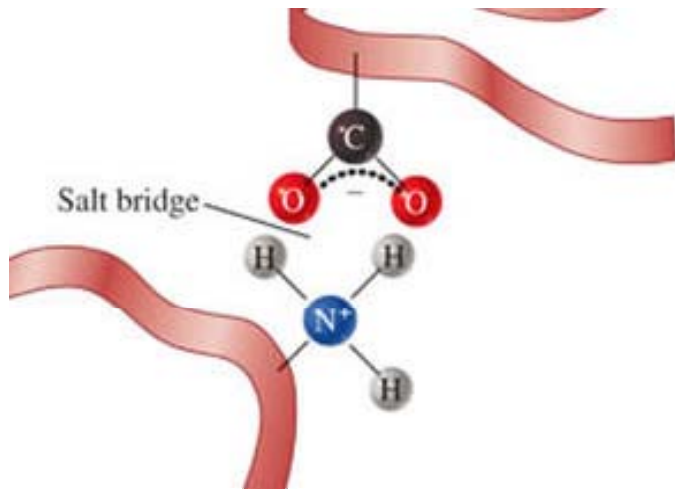
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# Noncovalent Interactions

- Charge-Charge Interactions
- Charge-Dipole Interactions
- Dipole-Dipole Interactions
- Charge-induced dipole Interactions
- Hydrogen Bonds
- van der Waals Interactions

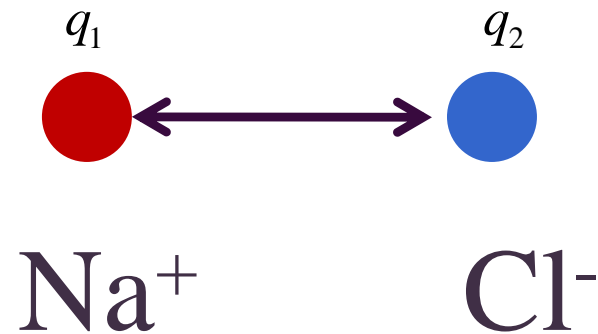
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# Charge-Charge Interactions



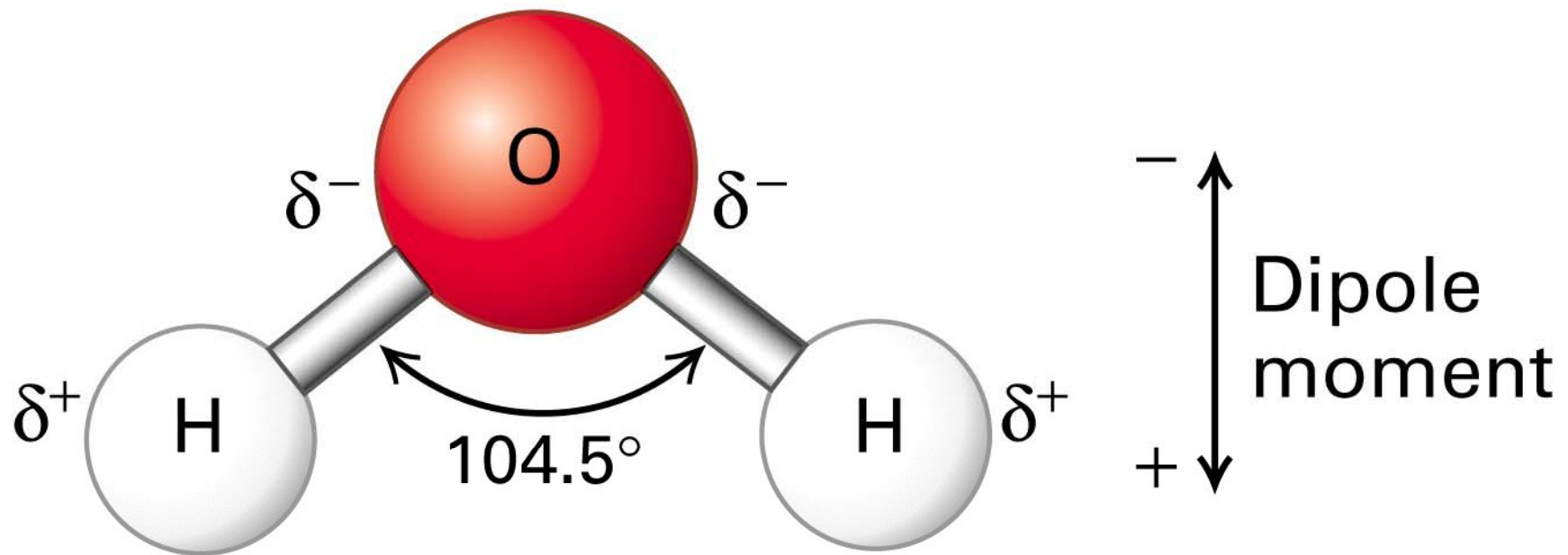
$$Force = k_c \times \frac{q_1 \times q_2}{r_{12}^2}$$

$$Potential = k_c \times \frac{q_1 \times q_2}{r_{12}}$$



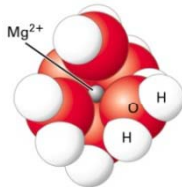
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# Dipole moment



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# Ion-Dipole Interaction



$$\text{Potential} = k_{\text{ion-dipole}} \times \frac{q \times u}{r^2}$$

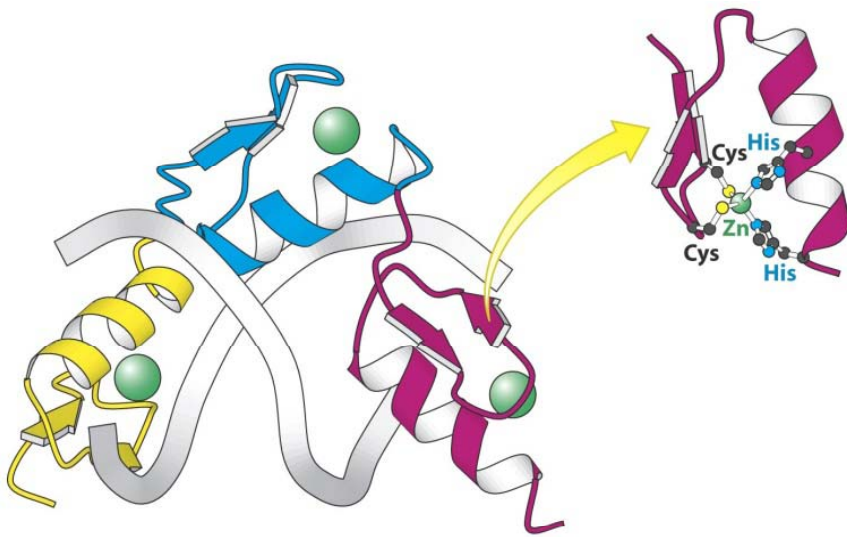
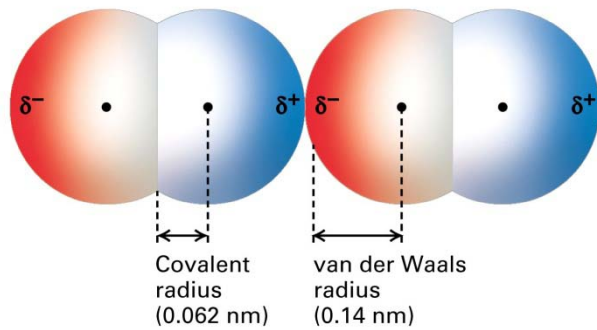


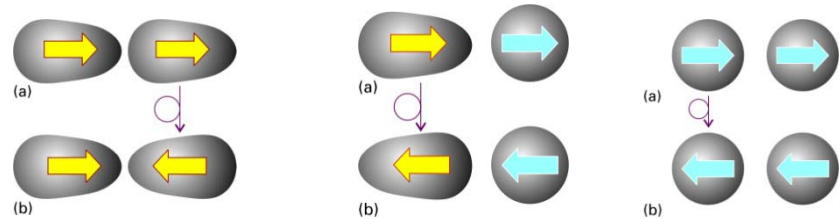
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# Dipole-Dipole Interactions



$$\text{Potential} = k_{\text{dipole-dipole}} \frac{u_1 \times u_2}{r^3}$$





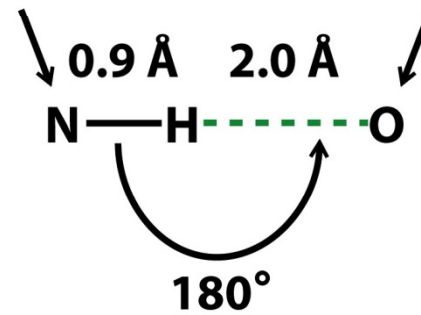
# Hydrogen Bonds

**Hydrogen-bond donor**      **Hydrogen-bond acceptor**

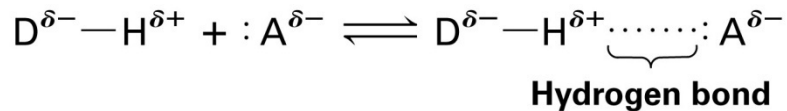
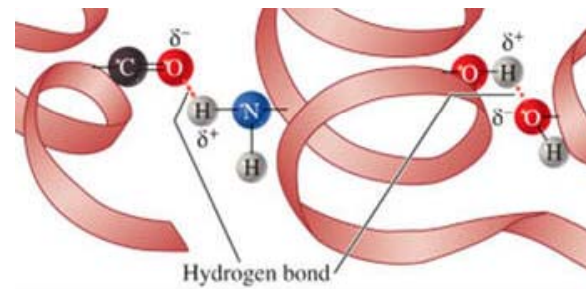


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**Hydrogen-bond donor**      **Hydrogen-bond acceptor**

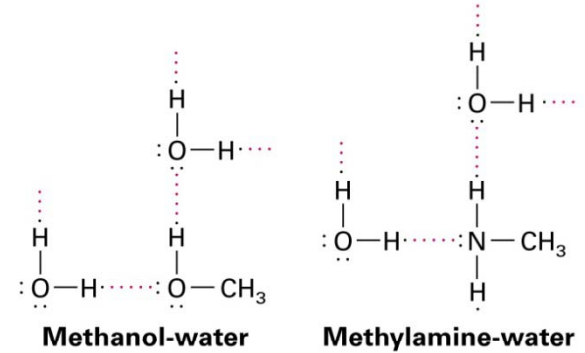
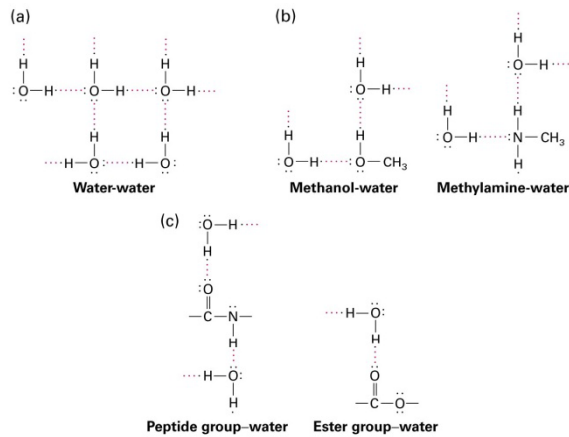
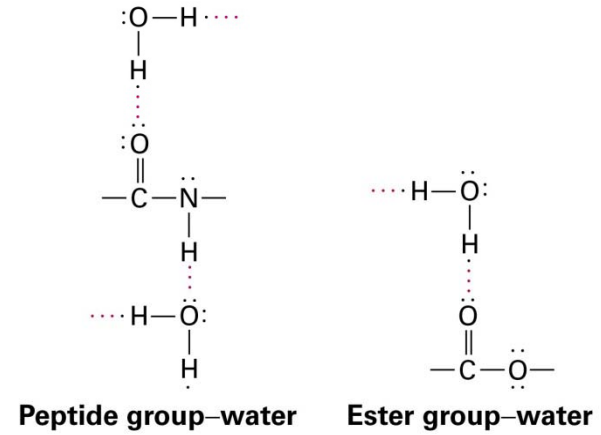
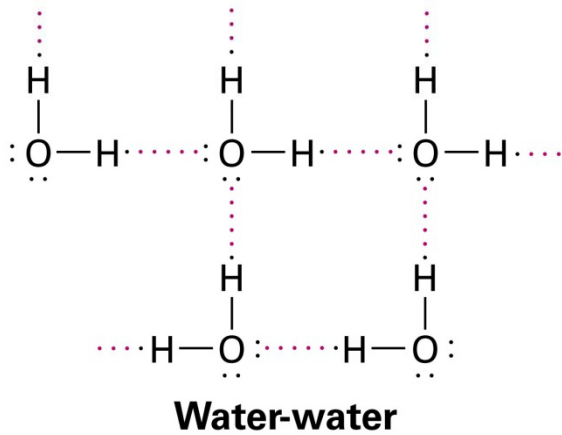


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# Hydrogen Bonds with Water



# Charge-Induced Dipole Interaction

$$\textit{Potential} = k_{\textit{ion-induced-dipole}} \times \frac{q}{r^4}$$

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# van der Waals Interactions

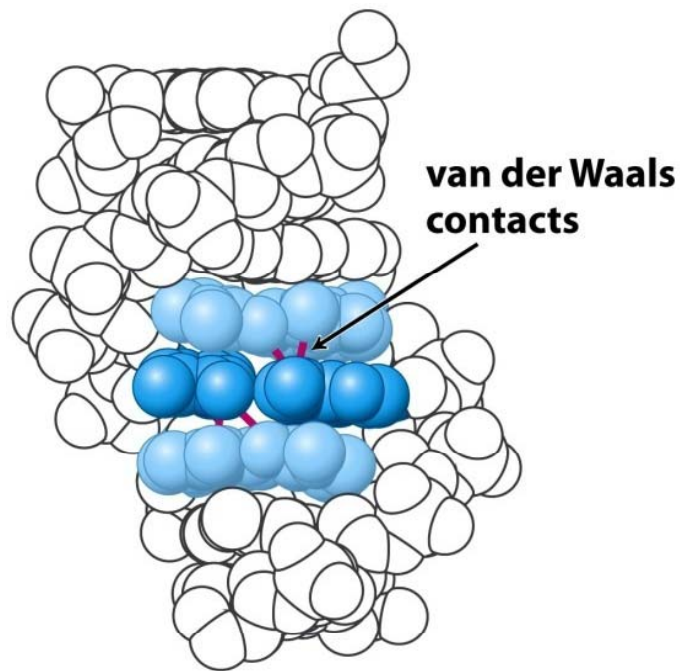


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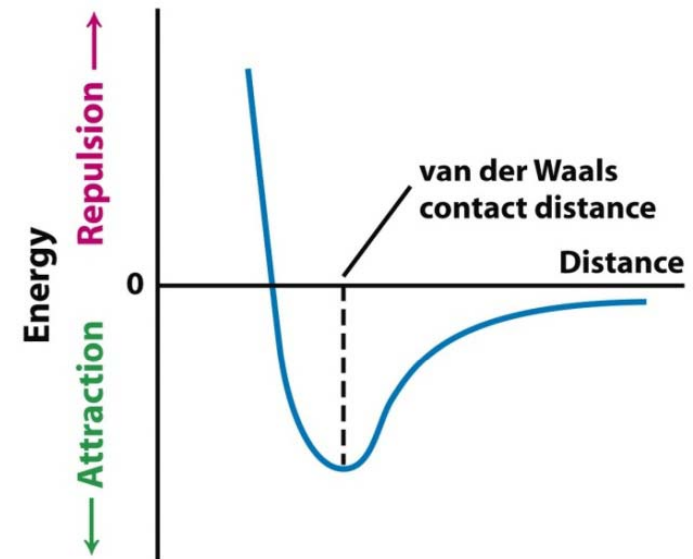
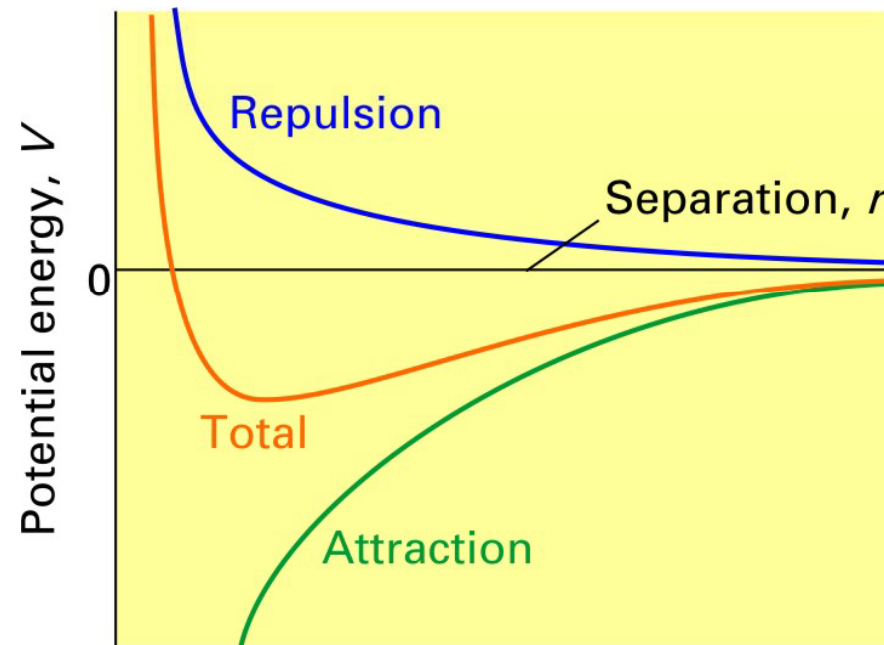


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# van der Waals Interactions

$$Potential = k_{van-der-Waals} \left\{ \left( \frac{\sigma}{r} \right)^{12} - \left( \frac{\sigma}{r} \right)^6 \right\}$$



# Distance Dependence

Interaction type	Distance dependence of potential energy	Typical energy (kJ mol <sup>-1</sup> )	Comment
Ion-ion	$1/r$	250.0	Only between ions
Dipole-dipole	$1/r^2$	15.0	
Induced dipole-dipole	$1/r^3$	2.0	Between stationary molecules
Induced dipole-rotation	$1/r^6$	0.3	Between rotating molecules
Induced dipole-dipole	$1/r^4$		
Ion-dipole	$1/r^2$	2.0	Between all types of molecules and ions
Induced dipole-rotation	$1/r^{12}$	2.0	Between all types of molecules and ions

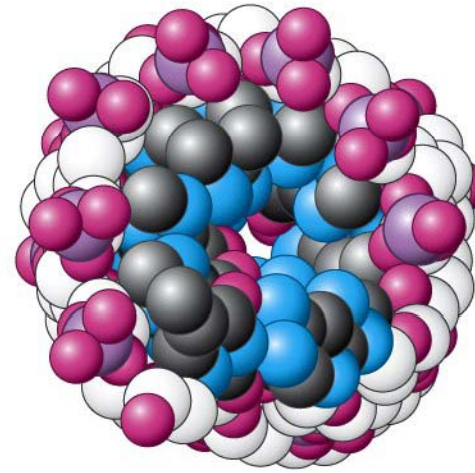
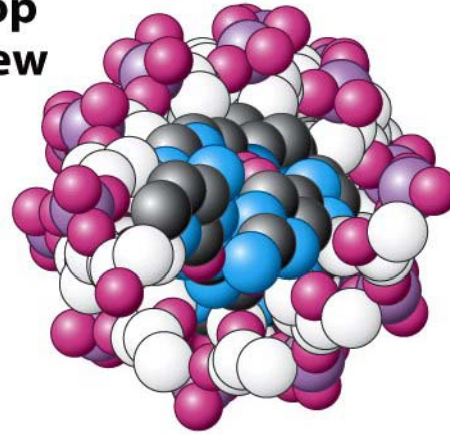
A hydrogen bond X-H ... Y is typically 20 kJ mol<sup>-1</sup> and occurs on contact for X, Y = N, O, or F

# Self-Assembly

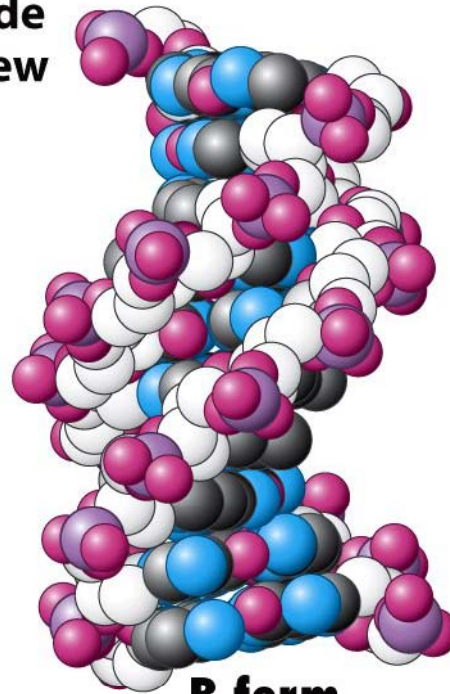
- By non-covalent interactions.

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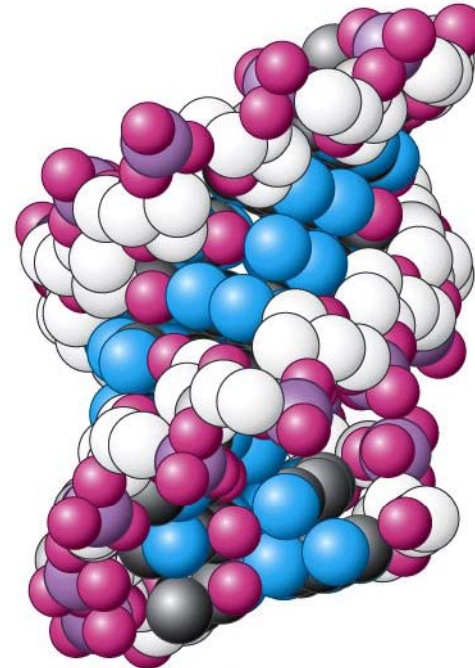
**Top  
view**



**Side  
view**



**B form**



**A form**

**Figure 28-3**  
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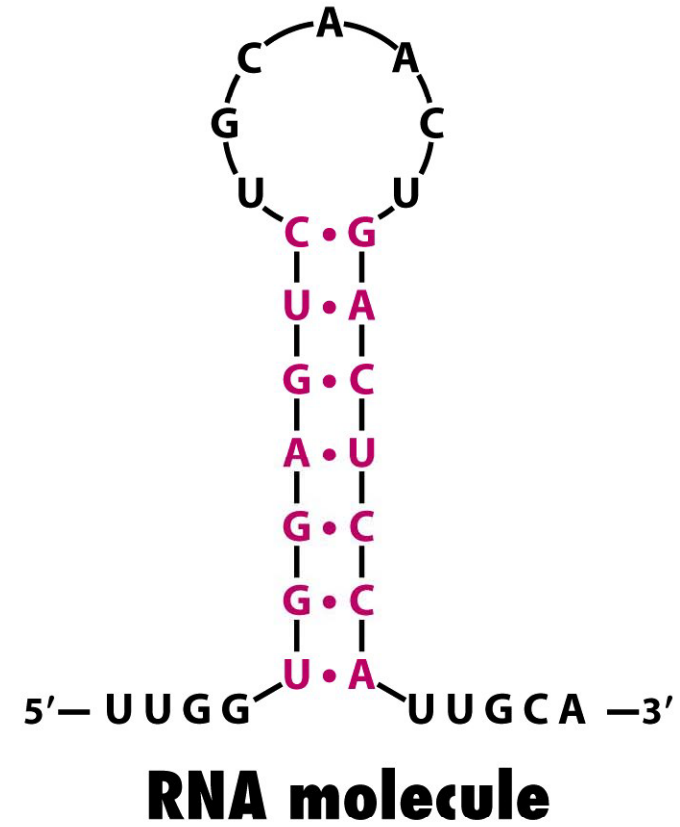
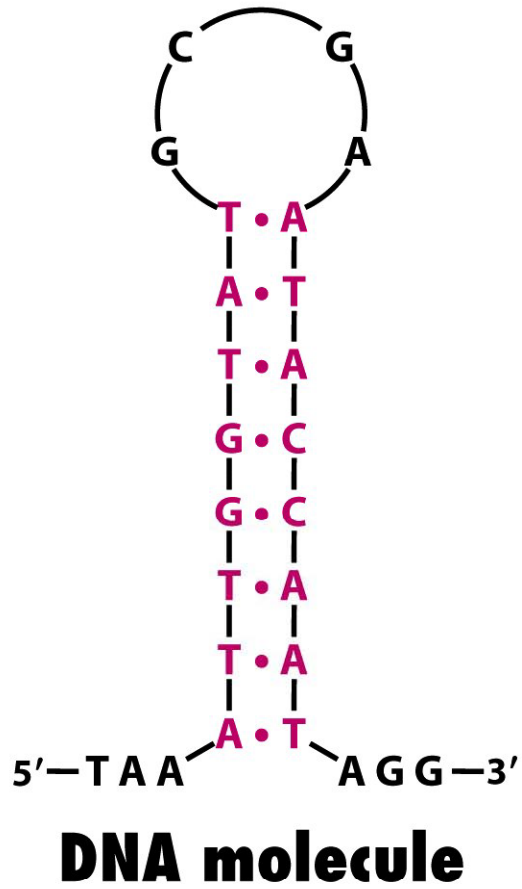


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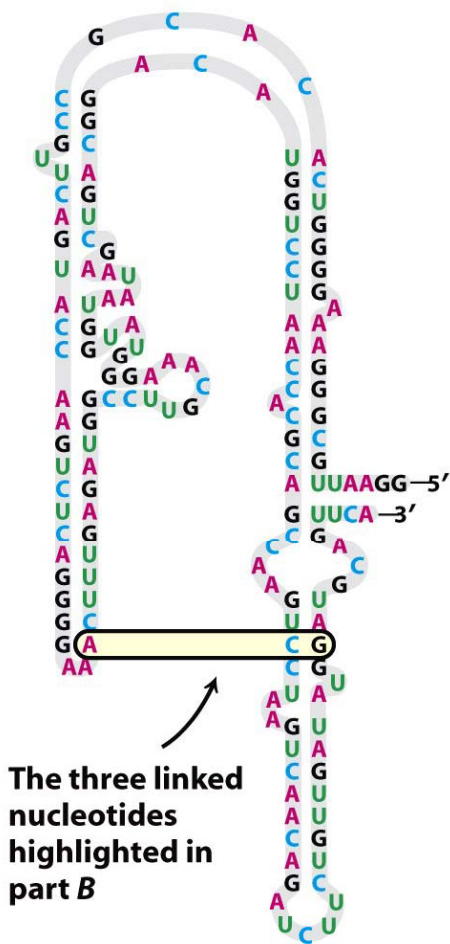


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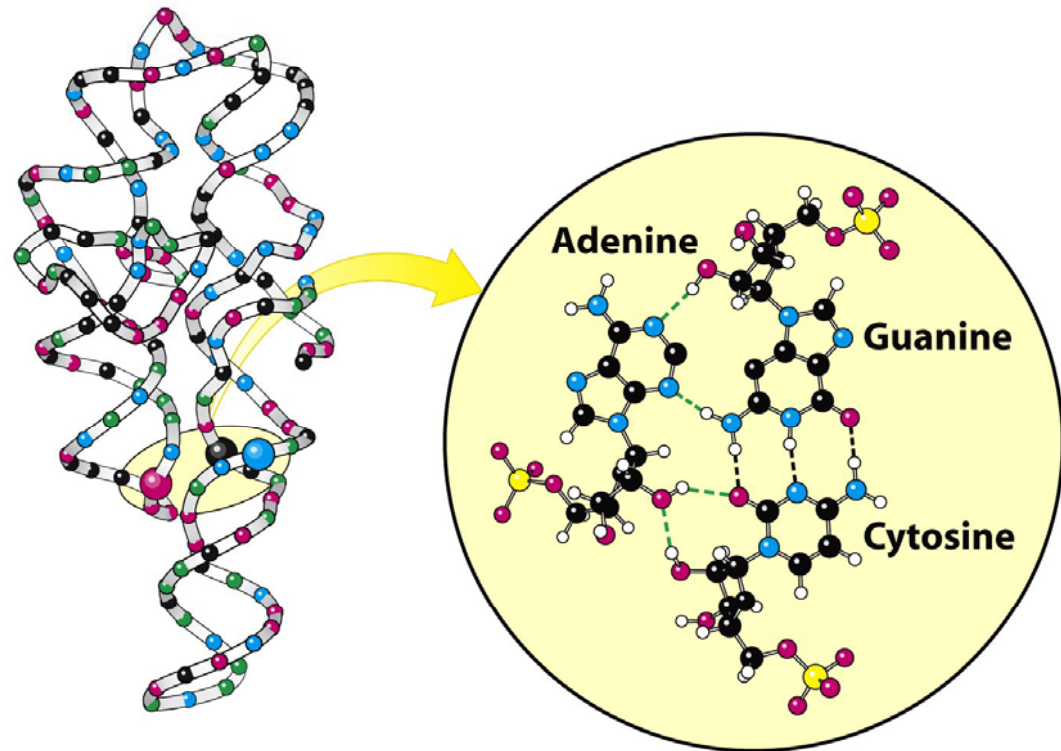


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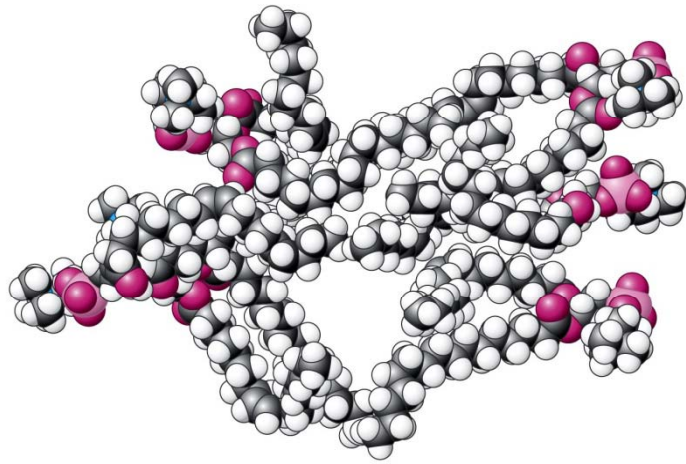


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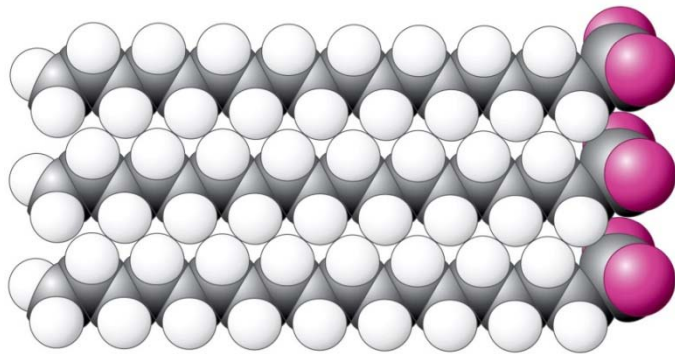
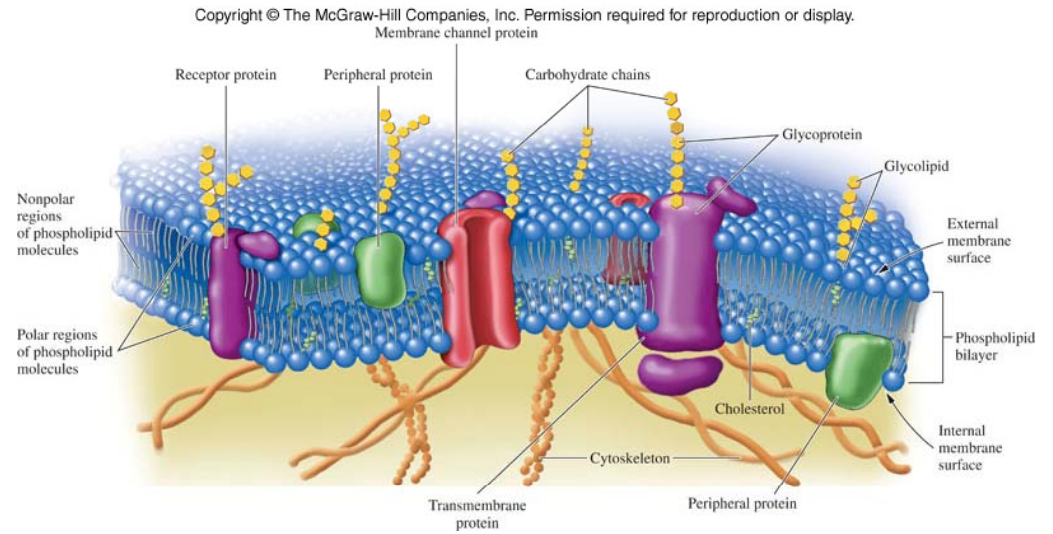
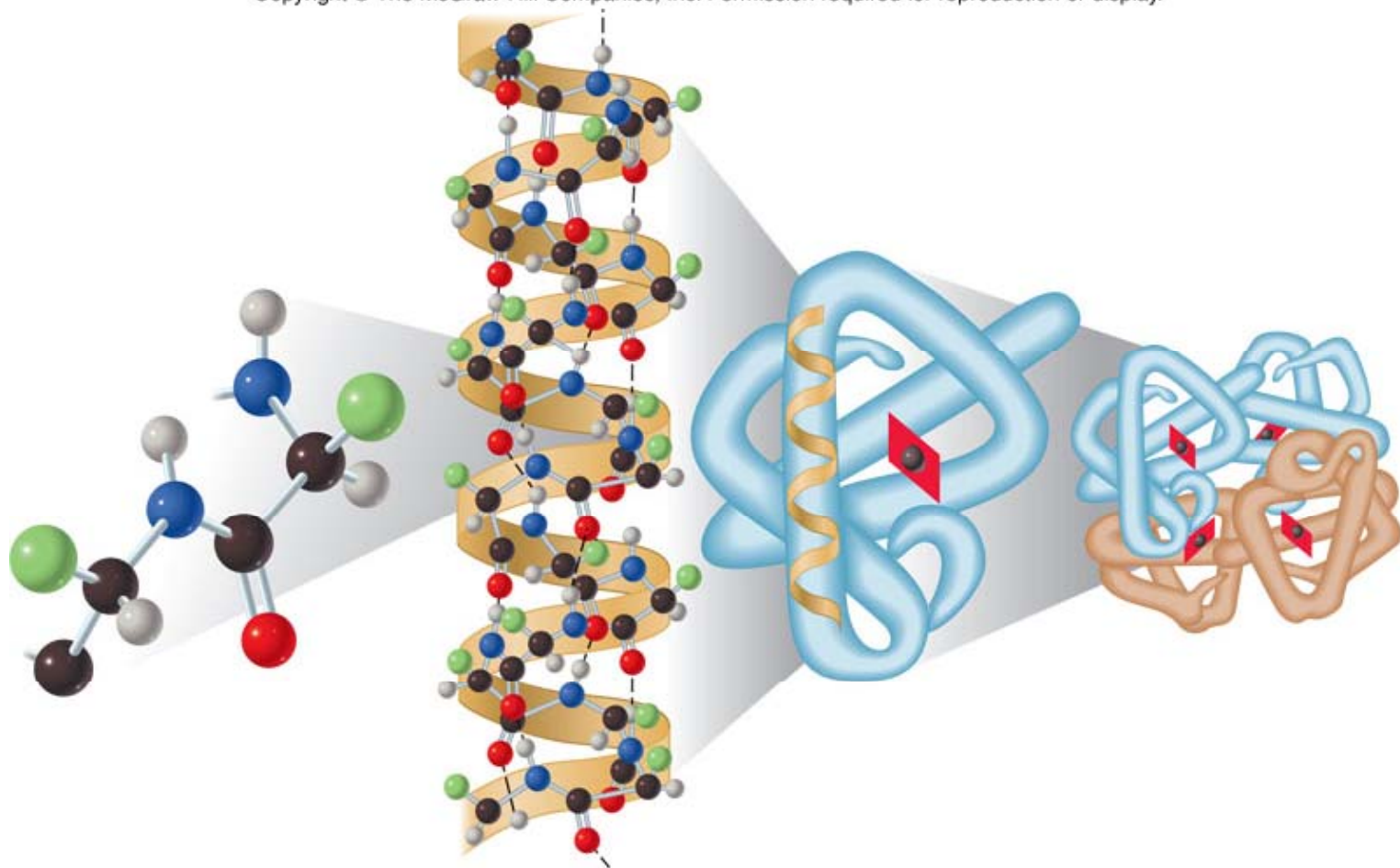


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(a) Primary structure

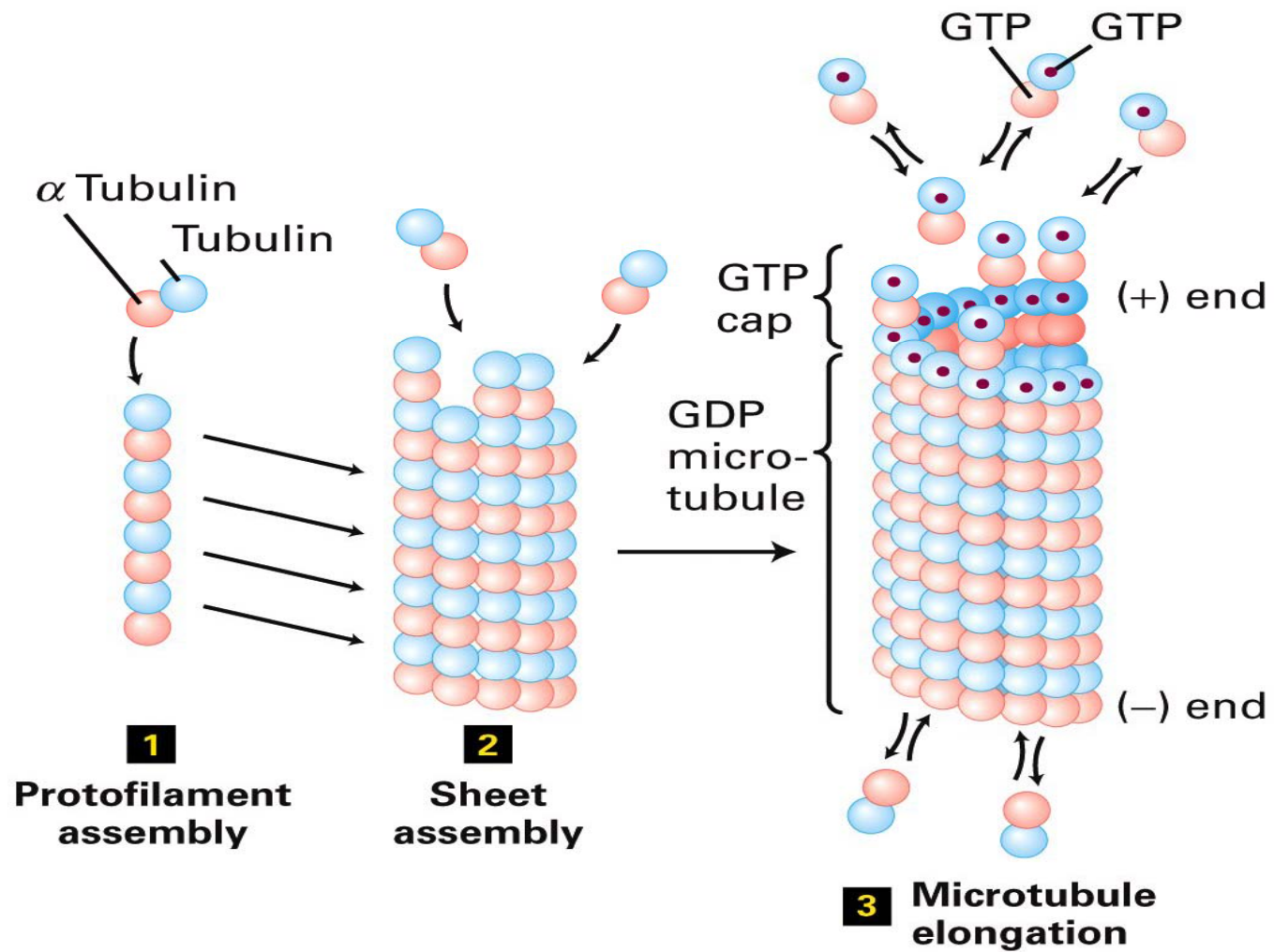
(b) Secondary structure

(c) Tertiary structure

(d) Quaternary structure



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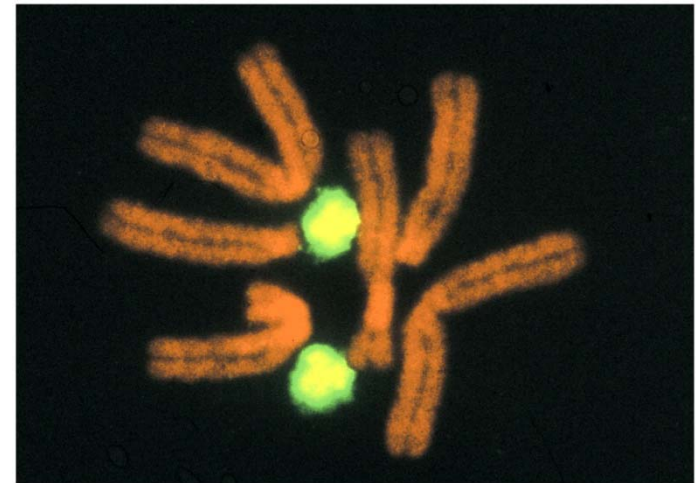


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