



$$\mathbf{R}_{BI} = \mathbf{R}_{BC} \mathbf{R}_{CD} \mathbf{R}_{DI} \Rightarrow B\mathbf{r} = \mathbf{R}_{BI} I\mathbf{r} \Leftrightarrow B\mathbf{r} = \mathbf{R}_I^B I\mathbf{r}$$

$$= \begin{pmatrix} \cos \psi & \sin \psi & 0 \\ -\sin \psi & \cos \psi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos \theta & 0 & -\sin \theta \\ 0 & 1 & 0 \\ \sin \theta & 0 & \cos \theta \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos \phi & \sin \phi \\ 0 & -\sin \phi & \cos \phi \end{pmatrix}$$

$$= \begin{pmatrix} \cos \beta \cos \gamma & \cos \alpha \sin \gamma + \cos \gamma \sin \alpha \sin \beta & \sin \alpha \sin \gamma - \cos \alpha \cos \gamma \sin \beta \\ -\cos \beta \sin \gamma & \cos \alpha \cos \gamma - \sin \alpha \sin \beta \sin \gamma & \cos \gamma \sin \alpha + \cos \alpha \sin \beta \sin \gamma \\ \sin \beta & -\cos \beta \sin \alpha & \cos \alpha \cos \beta \end{pmatrix}$$

$$\mathbf{R}_{IB} = \mathbf{R}_{BI}^T$$

$$= \begin{pmatrix} \cos \beta \cos \gamma & -\cos \beta \sin \gamma & \sin \beta \\ \cos \alpha \sin \gamma + \cos \gamma \sin \alpha \sin \beta & \cos \alpha \cos \gamma - \sin \alpha \sin \beta \sin \gamma & -\cos \beta \sin \alpha \\ \sin \alpha \sin \gamma - \cos \alpha \cos \gamma \sin \beta & \cos \gamma \sin \alpha + \cos \alpha \sin \beta \sin \gamma & \cos \alpha \cos \beta \end{pmatrix}$$