9.2. By definition, $\mathrm{E}[\exp(i\alpha \cdot G^n)] = \exp(-\frac{1}{2}\alpha \cdot Q^n\alpha)$ for all $\alpha \in \mathbf{R}^k$, where $Q^n_{ij} = \mathrm{E}[G^n_i G^n_j]$. Therefore, $\lim_n \mathrm{E}[\exp(i\alpha \cdot G^n)] = \exp(-\frac{1}{2}\alpha \cdot Q\alpha)$. Evidently, Q is nonnegative-definite because Q^n is. Also, Q is symmetric. Therefore, $\exp(-\frac{1}{2}\alpha \cdot Q\alpha)$ is the characteristic function of a Gaussian vector with covariance matrix Q (Theorem 9.5). The convergence theorem for characteristic functions finishes the proof.

9.5. Because W is a.s. continuous, $I(t) = \int_0^t W(s)\,ds$ is a Riemann integral, and is continuously-differentiable in t (fundamental theorem of calculus). We can also approximate $I(t)$ as a Riemann sum:

$$I(t) = \lim_{n\to\infty} \frac{1}{N} \sum_{i=1}^{N} W\left(\frac{it}{N}\right) \qquad \text{a.s.}$$

Because the vector $(W(t/N), \ldots, W(t))$ is Gaussian, $I(t)$ is the limit of linear combinations of Gaussians, whence it is Gaussian (Problem **9.2**).