1. Ester

2. An anhydride.

3. ArOH is a poor nucleophile, and so needs to be deprotonated (to increase nucleophilicity) prior to attack on the carbonyl group.


   Chichibabin reaction: False. *Not nucleophilic aromatic substitution on a pyridine ring.*

5. The equilibrium favors *heroin* because the ester (heroin) has greater resonance stabilization than the thioester on the morphine side.

6. Hydrolysis of heroin *group 2* is faster because this group has a better leaving group. *ArOH (the phenol) has resonance stabilization of one oxygen atom lone pair, whereas ROH (the alcohol) lacks this stabilization.*

7. (a) This change makes the hydrolysis faster because this new structure has a larger $\delta^+ C=O$ (is more electrophilic) due to the electron-withdrawing inductive effect of the CF$_3$ group. *The leaving group is ArOH, which is not altered by this change.*

   (b) This change makes the hydrolysis faster because this new structure has less steric hindrance at the C=O group. *A 'more electrophilic' reasoning can be used if it was not also used in part (a). The leaving group is ArOH, which is not altered by this change.*

8. (a) NR. *NaBH$_4$ does not reduce esters.*
10. Glucose $\rightarrow$ glucuronic acid: *Oxidized*. *Two C–O bonds are added.*

Glucuronic acid $\rightarrow$ morphine glucuronide: *Neither*. *No C–O or C–H bonds are added.*

11. The OH (a special circumstances leaving group) must be converted into water (a moderate leaving group) first. An $S_N2$ mechanism does not operate because the nucleophile (MOH) is poor and the leaving group is modest. OK to use HB/B instead of EnzH/Enz.

12. Recall that LiAlH$_4$ produces amines from amides. Thus we need to add a carbonyl group in the appropriate spot:

13. Equilibrium A has $K_{eq} \sim 1$ but equilibrium B has $K_{eq} << 1$ because equilibrium A has equal resonance stabilization (none) on both sides, whereas equilibrium B has more resonance stabilization on the ester side. *Recall that an equilibrium favors the more stable side.*

14. The OH to phosphate conversion is necessary because OH is a poor (special circumstances) leaving group. Also acceptable: The amine would convert the carboxylic acid into a carboxylate, thereby rendering it highly resistant to nucleophilic attack. Changing OH to phosphate removes the acid proton.

15. Ester, carboxylic acid, carboxylate, thioester, acid chloride (or acyl chloride), anhydride (or acid anhydride), and amide. *Some other functional groups not discussed in lecture may also be acceptable, such as carbonate.*

16. Anhydride (or acid anhydride).

17. **Name of carbonyl fate #1**: Accept nucleophile at carbon. *"Not likely" is incorrect because we learned in lecture that anhydrides react with weak oxygen nucleophiles such as water, even without acid catalysis.*

Illustration: The carbonyl bonded to the methyl is attacked because this carbonyl has less steric hindrance.

**Name of carbonyl fate #2**: Accept electrophile (usually proton) at oxygen.

Illustration: Not likely because carbonyl protonation requires a strong acid (H$_3$O$^+$ or stronger), which is not present.

**Name of carbonyl fate #3**: Be deprotonated; form enolate.

Illustration: Not likely because enolate formation requires a strong base (usually HO$^-$ or stronger), which is not present.
18. Same logic as $pK_a$ values for a ketone, a $\beta$-diketone, and an ester (OCATSA 27.02).

19. The reaction of the previous question is an example of a thioester Claisen condensation reaction.

20. Organometallic compound: 9(a) - $CH_3CH_2MgBr$

Nucleophilic carbonyl substitution without a tetrahedral intermediate: 0 This is just not possible!