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Host-Guest Sensory System of Dansyl-Modified β-Cyclodextrin for Detecting Steroidal Compounds by Dansyl Fluorescence

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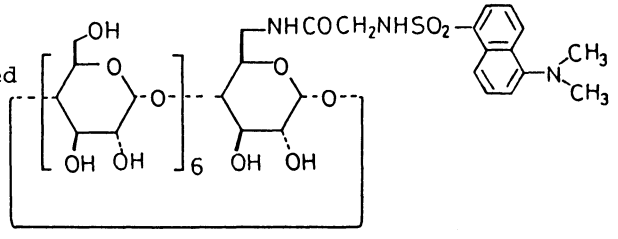
Dansyl-modified β-cyclodextrin decreases its fluorescence intensity upon guest binding, and this phenomenon was used to detect steroidal compounds. This system exhibited remarkable molecular recognition, showing high sensitivities for ursodeoxycholic acid and chenodeoxycholic acid.

Cyclodextrins are torus-shaped cyclic oligomers of D-glucopyranose, and can include a variety of organic compounds in their central cavities in aqueous solution.[1] They have been used as microscopic vessels or enzyme models, in which reactions are accelerated or stereochemically controlled due to the constrained geometries of substrates or the lipophilic nature of the cavity that is different from that of the bulk water. Since cyclodextrins are spectroscopically inert, the inclusion phenomena have usually been observed by using spectroscopically active guests that exhibit changes in absorption or fluorescence spectra upon complexation with cyclodextrins. Cyclodextrins, however, can be converted into spectroscopically active compounds by modification with chromophores, and spectroscopically inert guests may be detected by spectral changes of the modified cyclodextrins. Recently, we have prepared modified cyclodextrins, which have naphthalene,[2] anthracene,[3] pyrene,[4,5] or ferrocene[6] unit, and actually observed guest-induced variations in circular dichroism, absorption, and fluorescence spectra. This property of modified cyclodextrins may be used to construct host-guest sensory



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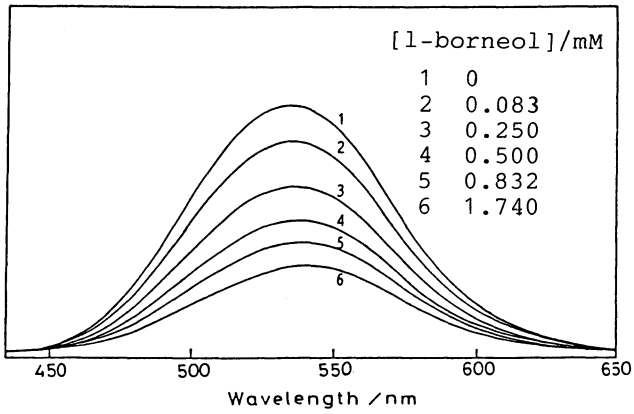
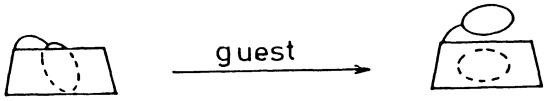


Fig. 1. Fluorescence spectra of **1** (2.25×10^{-6} M) in a 10% dimethyl sulfoxide aqueous solution in the absence and presence of l-borneol. Excitation wavelength was 370 nm.

systems with which a number of molecular species can be detected. In the previous report,[5] we have shown that pyrene-appended γ-cyclodextrin, which forms an association dimer that is converted into 1:1 host-guest complexes upon guest addition, is capable of detecting various guests by changing the monomer and excimer emission intensities. We wish to report here a novel host-guest sensory system which works monomolecularly (Eq. 1), showing remarkable molecular recognition in guest binding.



(1)

Dansyl-modified β-cyclodextrin (**1**) was prepared by reaction of dicyclohexylcarbodiimide, dansylglycine, and 6-deoxy-6-amino-β-cyclodextrin in N,N-dimethylformamide. Purificaton on a CM-Sephadex column afforded **1** as a yellow powder (yield 9%).[7]

Figure 1 shows fluorescence spectra of **1** in a 10% dimethyl sulfoxide aqueous solution in the presence and absence of l-borneol. The spectrum of **1**, alone, exhibits a fluorescence peak at 535 nm, and the fluorescence intensity decreases with increasing l-borneol concentration. This guest-induced variation in the fluorescence intensity suggests that the dansyl moiety moves from the interior of the hydrophobic cavity toward the bulk water environment outside the cavity. This argument is consistent with the fact that the fluorescence of the dansyl unit is enhanced in hydrophobic microenvironment of enzymes or micelles.[8] When the fluorescence intensity is abbreviated as I° for **1**, alone, and I for a mixture of **1** and guest, the $\Delta I/I^\circ$ value, where ΔI is $I^\circ - I$, can be used as a factor reflecting the sensitivity of the system to the guest. Figure 2 (A) shows the $\Delta I/I^\circ$ values obtained with steroids and l-borneol at 0.1 mM (M = mol dm^{-3}). It is obvious that ursodeoxycholic acid (**9**) and chenodeoxycholic acid

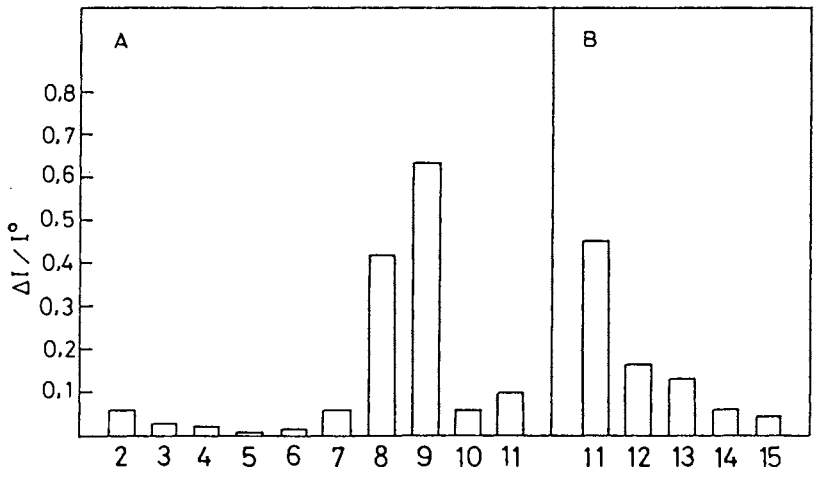
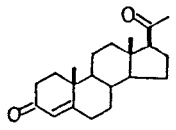
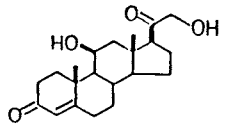


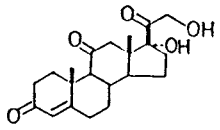
Fig. 2. The sensitivity factor $\Delta I/I^{\circ}$ of **1** (2.25×10^{-6} M) for various guests (A, 0.1 mM; B, 1.0 mM).



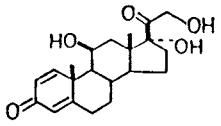
progesterone (2)



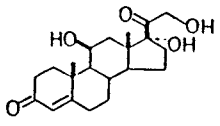
corticosterone (3)



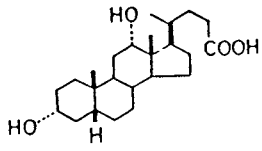
cortisone (4)



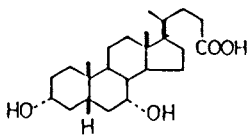
prednisolone (5)



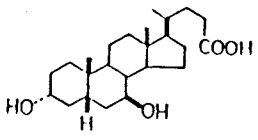
hydrocortisone (6)



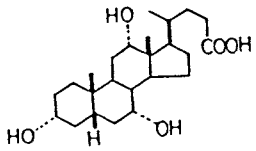
deoxycholic acid (7)



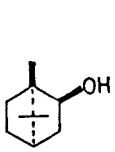
chenodeoxycholic acid (8)



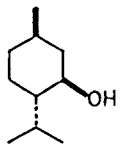
ursodeoxycholic acid (9)



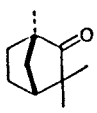
cholic acid (10)



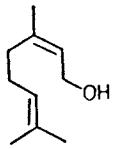
l-borneol (11)



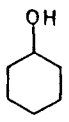
l-menthol (12)



l-fenchone (13)



nerol (14)



cyclohexanol (15)

(**8**) are detected with remarkably high sensitivities, exhibiting 0.63 and 0.42 for $\Delta I/I^{\circ}$, respectively. Although deoxycholic acid (**7**) is different from these steroids only in the position of one hydroxyl group, it is detected with much lower sensitivity. Cholic acid (**10**), which bears one more hydroxyl group than **8** and **9**, is hardly detected probably due to its increased polarity. Ketosteroids that bear two (corticosterone (**3**) and cortisone (**4**)) and three (prednisolone (**5**) and hydrocortisone (**6**)) hydroxyl groups are difficult to be detected with this system. Progesterone (**2**), which has no hydroxyl group and is more hydrophobic than the other ketosteroids, is detected with higher but still limited sensitivity. Although l-borneol is detected with sensitivity higher than those of many of the steroids, its $\Delta I/I^{\circ}$ value is much smaller than the values of ursodeoxycholic acid and chenodeoxycholic acid. Figure 2 (B) shows the results of five guests including l-borneol measured at 1.0 mM. The order of sensitivity, l-borneol>l-menthol>l-fenchone>nerol>cyclohexanol, shows that remarkable molecular recognition is attained also for these guests.

In conclusion, the sensory system of **1** exhibits remarkable molecular recognition ability in detecting organic compounds by its fluorescence. Particularly, ursodeoxycholic acid and chenodeoxycholic acid have been detected by this system with high sensitivities. Further work with many other guests is needed to clarify the relationship between guest structure and the sensitivity of this system.

References

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7) Satisfactory spectral data were obtained. Anal. Found: C, 46.47; H, 6.25; N, 2.23; S, 1.93%. Calcd for $C_{15}H_{85}O_{37}N_3S\cdot H_2O$: C, 46.63; H, 6.08; N, 2.91; S, 2.22%. MS (FAB) M/Z 1424 ($[M + H]^+$).

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