3.6 LOI CONTINUE 3

cours 18

Au dernier cours, nous avons vu

Loi exponentielle

$$X \sim Exp(\lambda) \qquad f(x) = \begin{cases} \lambda e^{-\lambda x} & 0 \leq x \\ 0 & sinon \end{cases}$$

$$F(x) = \begin{cases} -e^{-\lambda x} + 1 & 0 \leq x \\ 0 & sinon \end{cases}$$

$$E(X) = \frac{1}{\lambda} \qquad \mathrm{Var}(X) = \frac{1}{\lambda^2}$$

Au dernier cours, nous avons vu

Loi normale

$$X \sim N(\mu, \sigma) \qquad\qquad f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Aujourd'hui, nous allons voir

- ✓ Loi normale

$$X \sim N(\mu, \sigma)$$

$$E(X) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{\infty} x e^{-\frac{(x-\mu)^2}{2\sigma^2}} \, dx$$

$$y = \frac{(x-\mu)}{\sigma}$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} x e^{-\frac{y^2}{2}} \, dy$$

$$dy = \frac{dx}{\sigma}$$

$$x = \sigma y + \mu$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} (\sigma y + \mu) e^{-\frac{y^2}{2}} \, dy$$

$$= \frac{\sigma}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y e^{-\frac{y^2}{2}} \, dy + \mu \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}} \, dy$$

$$X \sim N(\mu, \sigma)$$

$$E(X) = \frac{\sigma}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y e^{-\frac{y^2}{2}} \; dy + \mu \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}} \; dy$$

$$= \frac{\sigma}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y e^{-\frac{y^2}{2}} dy + \mu$$

$$u = \frac{y^2}{2}$$

$$du = ydy$$

$$= \frac{\sigma}{\sqrt{2\pi}} \int e^{-u} \; du + \mu$$

$$= \overbrace{-\frac{\sigma}{\sqrt{2\pi}} e^{-\frac{y^2}{2}} \Big|_{-\infty}^{\infty}}^{0} + \mu \quad = \mu$$

$$X \sim N(\mu, \sigma)$$

$$\mathrm{Var}(X) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{\infty} (x-\mu)^2 e^{-\frac{(x-\mu)^2}{2\sigma^2}}\, dx$$

$$y = \frac{x-\mu}{\sigma}$$

$$dy = \frac{dx}{\sigma}$$

$$x - \mu = \sigma y$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} (x-\mu)^2 e^{-\frac{y^2}{2}}\, dy$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} (\sigma y)^2 e^{-\frac{y^2}{2}}\, dy$$

$$= \frac{\sigma^2}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y^2 e^{-\frac{y^2}{2}}\, dy$$

$$X \sim N(\mu, \sigma)$$

$$\mathrm{Var}(X) = \frac{\sigma^2}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y^2 e^{-\frac{y^2}{2}}\ dy$$

$$= \frac{\sigma^2}{\sqrt{2\pi}} \left(-y e^{-\frac{y^2}{2}} \Big|_{-\infty}^{\infty} + \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}}\ dy \right)$$

$$u = y \qquad dv = y e^{-\frac{y^2}{2}} dy$$

$$du = dy \qquad v = \int y e^{-\frac{y^2}{2}} dy \qquad w = \frac{y^2}{2}$$

$$dw = y dy$$

$$= \int e^{-w} dw$$

$$= -e^{-w} \quad = -e^{-\frac{y^2}{2}}$$

$$X \sim N(\mu, \sigma)$$

$$\mathrm{Var}(X) = \frac{\sigma^2}{\sqrt{2\pi}} \int_{-\infty}^{\infty} y^2 e^{-\frac{y^2}{2}} \, dy$$

$$= \frac{\sigma^2}{\sqrt{2\pi}} \left(\cancelto{0}{-y e^{-\frac{y^2}{2}} \Big|_{-\infty}^{\infty}} + \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}} \, dy \right)$$

$$= \frac{\sigma^2}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}} \, dy$$

$$= \sigma^2 \left(\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{-\frac{y^2}{2}} \, dy \right) = \sigma^2$$

$$X \sim N(\mu, \sigma)$$

$$E(X) = \mu \qquad\qquad \mathrm{Var}(X) = \sigma^2$$

$$X \sim N(\mu, \sigma)$$

Comment faire pour calculer

$$P(X \leq a) \ = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{a} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \ dx$$

Mais la fonction n'a pas de primitive analytique

Il faut donc utiliser les séries de Taylor!

Ouin…

Si $\quad X \sim N(\mu, \sigma)$

on a vu que $\quad Z = \dfrac{X - \mu}{\sigma} \quad$ est centré réduite

c'est-à-dire

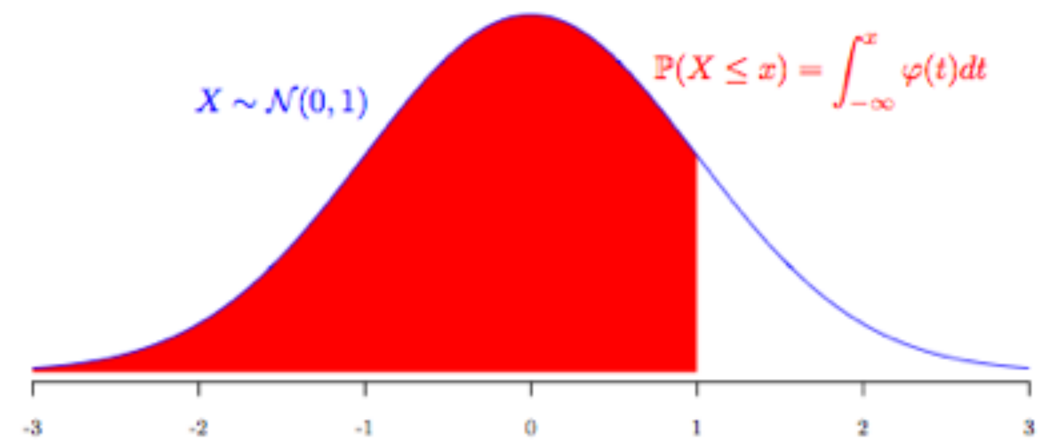
$$E(Z) = 0 \qquad\qquad \mathrm{Var}(Z) = 1$$

et donc

$$Z \sim N(0, 1)$$

Il suffit donc de calculer les séries de Taylor pour une seule loi normale

Mais on ne fera pas ça…

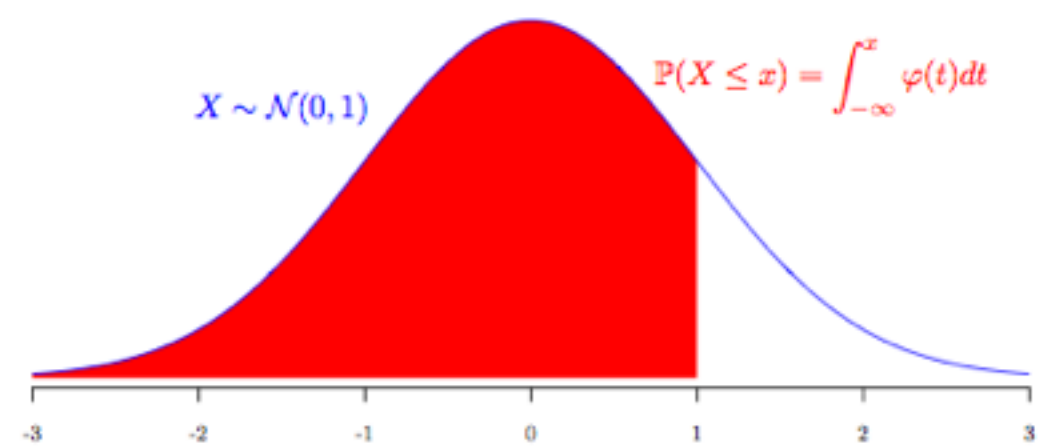


Quelqu'un l'a déjà fait pour nous.

On va utiliser une table de la loi normale

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

$$P(Z \leq 1,64) \approx 0,9495$$



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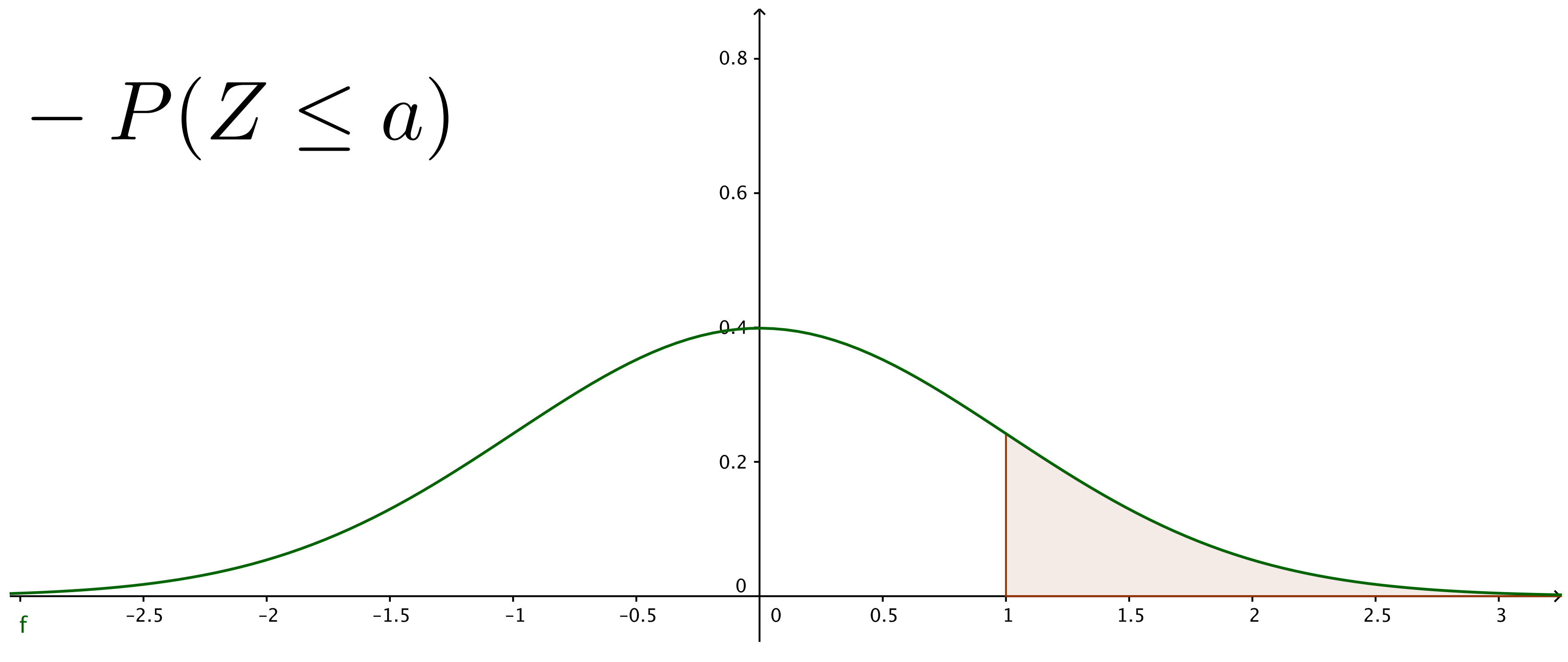
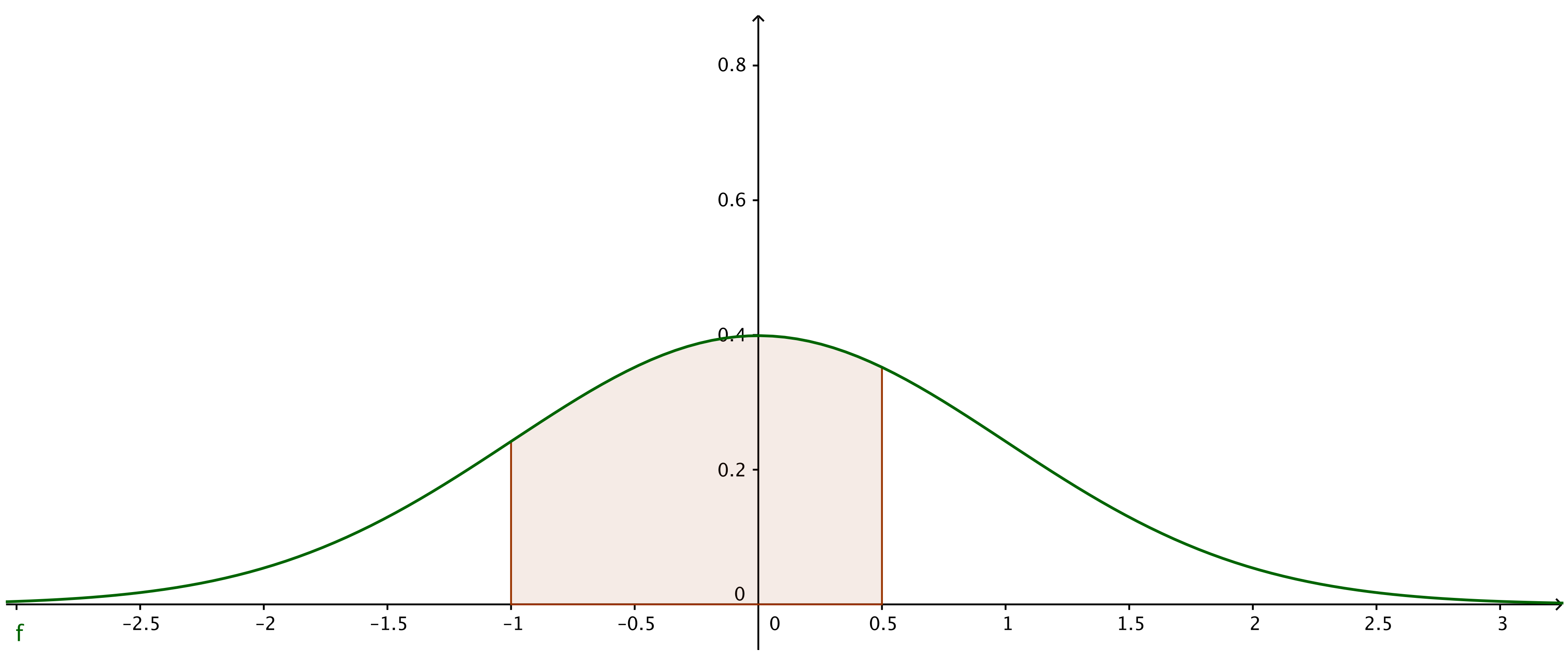
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

$$P(Z \leq a)$$

$$P(Z \geq a) = 1 - P(Z \leq a)$$



$$P(a \leq Z \leq b) = P(Z \leq b) - P(Z \leq a)$$

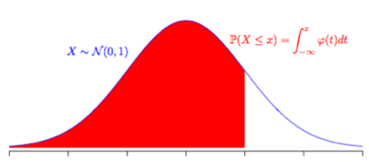


Exemple On achète une citrouille au marché. Son poids en livre suit une loi normale $X \sim N(5, 3)$

Quelle est la probabilité qu'une citrouille prise au hasard ait un poids entre 6 et 7 livres?

$$P(6 \leq X \leq 7) = P\left(\frac{6-5}{3} \leq \frac{X-5}{3} \leq \frac{7-5}{3}\right)$$

$$= P\left(\frac{1}{3} \leq Z \leq \frac{2}{3}\right)$$



$$= P\left(Z \leq \frac{2}{3}\right) - P\left(Z \leq \frac{1}{3}\right)$$

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2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

$$= P(Z \leq 0,67) - P(Z \leq 0,33)$$

$$= 0,7486 - 0,6293 \; = 0,1193$$

Faites les exercices suivants

3.49 à 3.59

Approximation d'une loi binomiale à l'aide de la loi normale.

$X \sim B(n,p)$ avec n suffisamment grand

$E(X) = np = \mu$

$\mathrm{Var}(X) = npq = \sigma^2$

Le théorème central limite.

$$X \approx N(np, \sqrt{npq})$$

$X \sim B(n,p)$ avec n suffisamment grand

Habituellement on utilise cette approximation si

$$n \geq 30$$

$$np \geq 5$$

$$nq \geq 5$$

$$X \approx N(np, \sqrt{npq})$$

Correction de continuité.

$$X \sim B(n, p) \qquad\qquad Y \sim N(np, \sqrt{npq})$$

$$P(X = a) \approx P\left(a - \frac{1}{2} \leq Y \leq a + \frac{1}{2}\right)$$

$$P(X \leq a) \approx P\left(Y \leq a + \frac{1}{2}\right)$$

$$P(X < a) \approx P\left(Y \leq a - \frac{1}{2}\right)$$

Exemple Une variable aléatoire compte le nombre de piles lors d'une série de 40 jets. On veut la probabilité d'obtenir 20 piles.

$$X \sim B(40; 0,5) \qquad E(X) = np = 20$$

$$\mathrm{Var}(X) = npq = 10$$

$$X \sim N(20, \sqrt{10})$$

$$P(X = 20) = P(19,5 \leq X \leq 20,5)$$

$$= P\left(\frac{19,5-20}{\sqrt{10}} \leq \frac{X-20}{\sqrt{10}} \leq \frac{20,5-20}{\sqrt{10}}\right)$$

$$= P\left(-0,16 \leq Z \leq 0,16\right)$$

$$= P\left(Z \leq 0,16\right) - P\left(Z \leq -0,16\right) = 0,1272$$

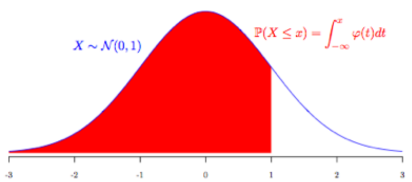
Faites les exercices suivants

3.60 et 3.61

Aujourd'hui, nous avons vu

$$X \sim N(\mu, \sigma)$$

$$E(X) = \mu \qquad \mathrm{Var}(X) = \sigma^2$$



$$Z = \frac{X - \mu}{\sigma} \qquad Z \sim N(0,1)$$

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990

$$X \sim B(n,p) \quad \Longrightarrow \quad X \approx N(np, \sqrt{npq})$$

Devoir: 3.49 à 3.61